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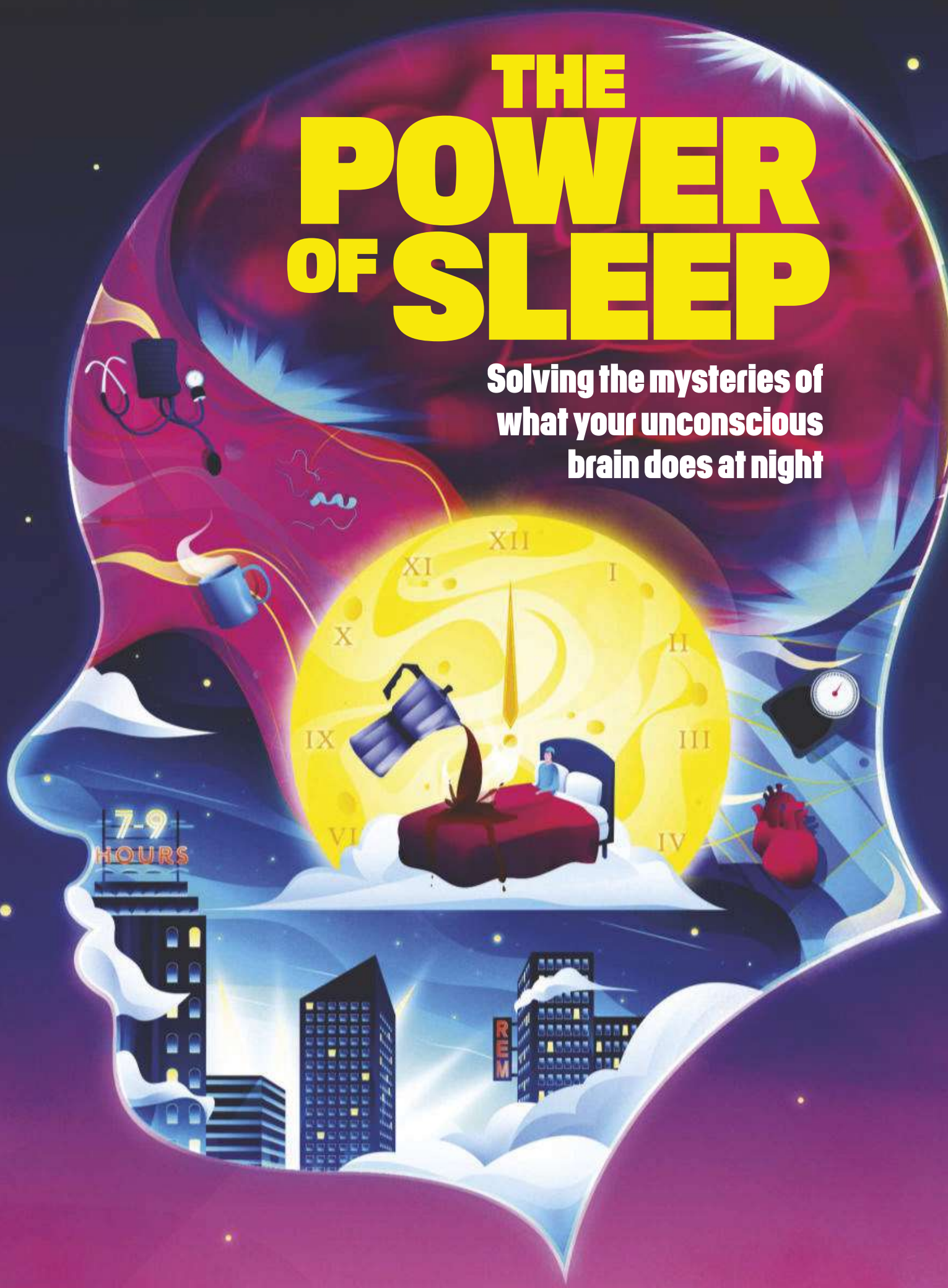

THE POWER OF SLEEP

Solving the mysteries of what your unconscious brain does at night

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How to keep your dog calm when you go back to the office

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FROM THE EDITOR

When was the last time you had a good night's sleep? By that I mean: you said goodbye to the waking world an hour or two earlier than usual, left your phone in another room and didn't set an alarm for the next morning. Sounds good doesn't it? But in reality, it's something few of us ever indulge in.

You might even feel like our sleeping hours are under threat. Celebs and self-proclaimed lifestyle gurus often boast about how little they sleep – productivity comes first. And how many of us are guilty of bringing our smartphones into bed, where a few TikToks or tweets quickly turn into hours of lost sleep? And let's not get into how the pandemic has wreaked havoc with our sleeping patterns..

Unfortunately, while we all struggle to get a decent rest, scientists are discovering just how important sleep is. Of course, we all know the consequences of pulling an all-nighter, but it seems that even just an hour of lost sleep can have a profound effect on our overall health and wellbeing. Head to p52 to get Dr Matthew Walker's guide to the latest discoveries in sleep research.

Also, over on our weekly podcast, where we take a deeper dive into the subjects we cover in the magazine, we've reached a big milestone: 1,000,000 listens! So if you enjoy the issue, do head over to the podcast where you can hear the team talking to some of the world's leading scientists and experts. **sciencefocus.com/science-focus-podcast**

Daniel Bennett, Editor

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COVER: CODY MUIR/POCKO THIS PAGE: BBC, ALAMY, GETTY IMAGES, DANIEL BRIGHT

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A former deputy editor at *Science Focus*, Ian left to work for a health title. But we're not bitter, it's just coincidence that we got him to find out about poo. →p32

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During the pandemic, many of us have spent more time with our pets, but how will they cope when we're in the office? Dog expert Melissa explains how you can help them. →p30

DR SARAH BERRY
If, like us, you often find yourself snacking between meals, it could be in your blood. Literally. Nutritionist Sarah tells us why. →p26

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ON THE BBC THIS MONTH...

Rockets In The Desert
Don't miss the repeat broadcast of this 2014 report on the Mojave Desert – the 'Silicon Valley of space'. Journalist Richard Hollingham speaks to the entrepreneurs, engineers and rocket scientists attempting to build a new industry of private spaceflight and exploration.
BBC Radio 4 Extra and BBC Sounds, 5 May, 2:30pm

Climate Change: Ade On The Frontline
Ade Adepitan visits the people on the frontline, whose lives have already felt the effects of the climate crisis. While the damage being done can be upsetting to witness, there is hope to be found in the innovative actions of affected communities.
Available now on iPlayer

CrowdScience
The *CrowdScience* programme is a must for lovers of our *Q&A* pages. This month, the experts answer questions including 'Why is learning stuff harder as you get older?'. The show might make you feel a bit better about your lack of learning during lockdown...
BBC World Service, Fridays at 8:30pm

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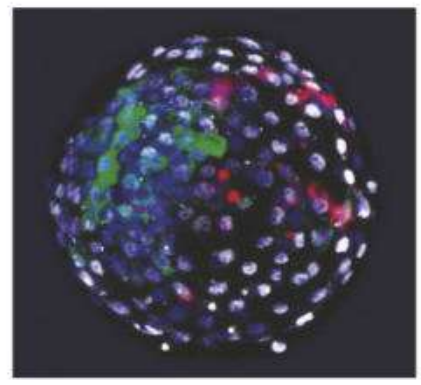

Scientists at the Salk Institute have created human-monkey 'chimera' embryos.

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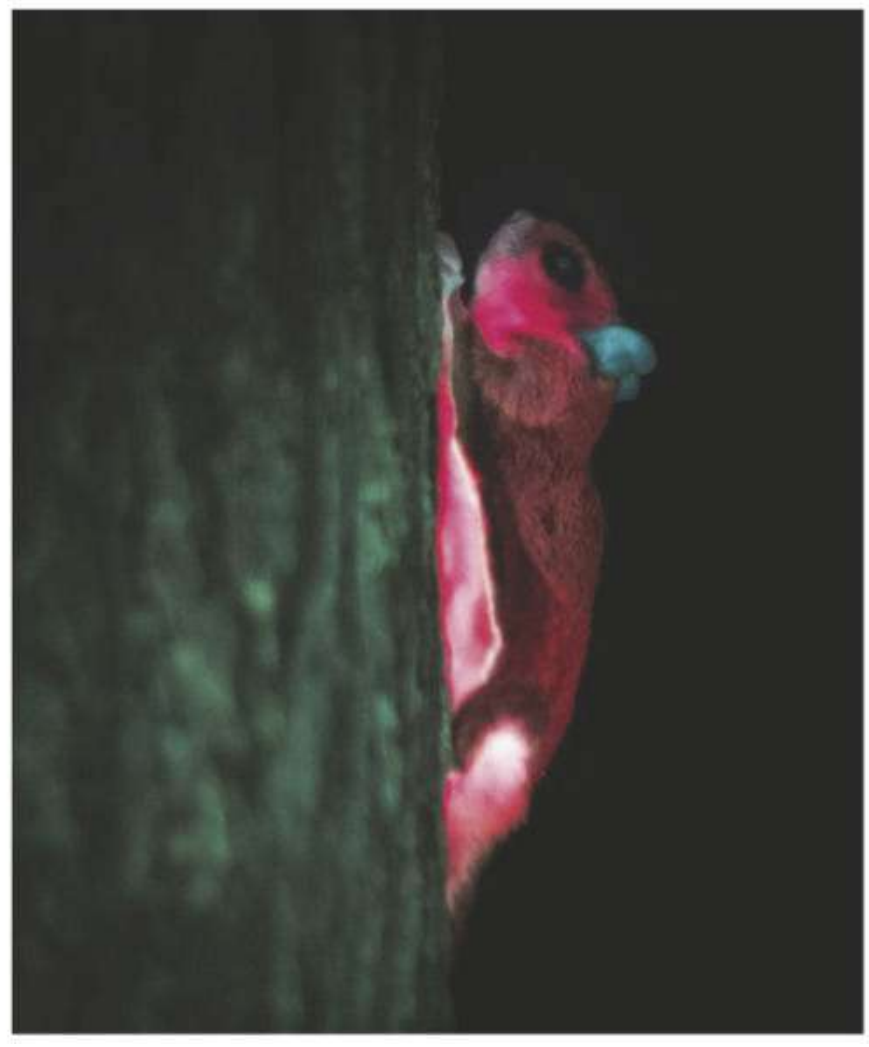

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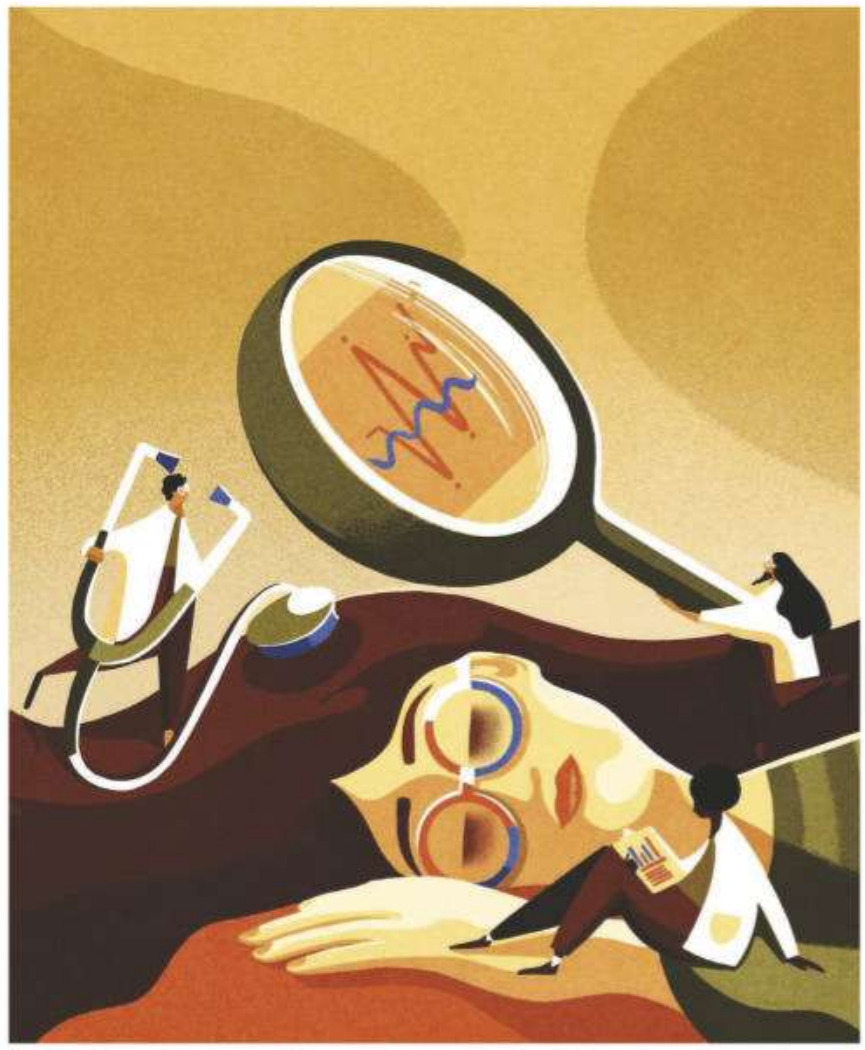

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"LOOT BOXES LOOK A LOT LIKE GAMBLING – YOU PAY MONEY TO GET A CHANCE AT SOMETHING YOU WANT"

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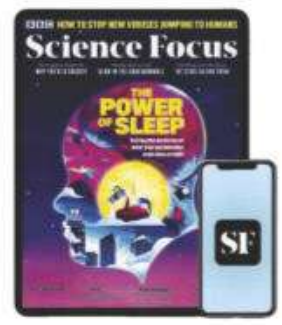

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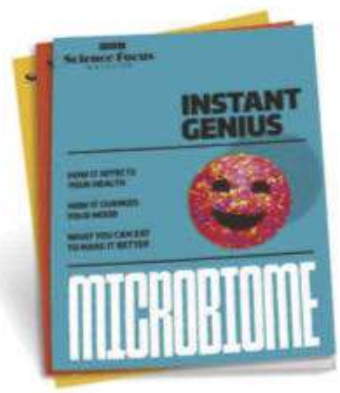

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EYE OPENER

The lab in a lake

LAKE BAIKAL, SIBERIA

The hunt for mysterious, high-energy events in space is starting somewhere unexpected: at the bottom of the deepest lake on Earth. Russian scientists are creating a huge neutrino detector 1,300m under the surface of Lake Baikal in the mountains of Siberia. Their quarry: subatomic particles that are difficult to detect because they interact so weakly with gravity and matter.

The telescope, called the Baikal Gigaton Volume Detector, is made of dozens of pressurised glass spheres, each containing photomultiplier tubes that can detect Cherenkov radiation – a flash of light generated when neutrinos pass through water. "It's the optical equivalent of the sonic boom you get when an aircraft exceeds the speed of sound," says Dr Susan Cartwright, a particle physicist at Sheffield University.

Rare, high-energy neutrinos are thought to come from the same unknown phenomenon in deep space as cosmic rays.

GETTY IMAGES

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EYE OPENER

Robot roots

PISA, ITALY

Pardon the pun, but machines that mimic plants are something of a growth area in robotics. Here, a researcher at Italy's Center For MicroBioRobotics demonstrates a 'plantoid', a robot designed to behave like a plant and move away from 'negative events' (things like chemicals in the soil) and towards 'positive' ones (nutrients). It's hoped robots like this could help find signs of water on Mars. Right now, they're being used to test soils and activate drones that tend to sick plants.

They're part of a wider trend called morphological computation, says Dr Peter J Bentley, a computer scientist at UCL. It's about rethinking robot design to optimise their function. "Think of the difference between a robot with a metal claw for a hand compared to one with a soft gripper," Bentley says. "The claw is difficult to control when handling delicate items and will often damage them, while the soft gripper is easy to control and protects items by being soft and flexible."

MARCO BURATTI/PARALLELOZERO

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How to get better pictures

Late spring, when animals are in abundance, is the perfect time to have a go at photographing wildlife. But don't despair if you live in the middle of a city – there are still plenty of subjects to photograph. These tips from award-winning cameraman* Sam Hobson*, along with recommended setups from* MPB*, the world's best marketplace for used photo and video kit, will help you get the best shots…

FIND OUT MORE
AT MPB.COM

of urban wildlife

SAM HOBSON PHOTOGRAPHY

1 GO ON A NATURE STAKEOUT

Animals make rewarding subjects for photography but are uncooperative models. To create great images, it pays to learn their habits. Observation will tell you which flowers attract the most bees, which perches are most popular among birds, and which ponds are frequented by frogs, allowing you to set up your camera at a site you know has a good chance of success. Some animals are crepuscular or nocturnal, so it is worth visiting the same spots at different times of day to discover what is about.

Consider using trail cams to keep a record of wildlife movements. If you have a path you suspect an animal is using, set your camera trap at a 45° angle to avoid triggering it too early, before the animal is big enough in the frame; or too late, capturing a tip of anonymous tail.

2 BECOME A PART OF THE LANDSCAPE

Any animal is liable to be spooked if approached by a person, spoiling not only the chance for a great photograph, but also the likelihood of them returning to the same spot again. It's better to choose your location, compose your shot, and wait for the wildlife to come to you.

Urban animals are more habituated to humans than their rural counterparts, and will likely ignore you if you stay still for long enough. Some species, such as foxes, are naturally inquisitive and might even reward your patience by coming to investigate your camera. A wide-angle lens in a low position works best for this kind of intimate shot. Improve your chances further by investing in a remote trigger, and free yourself to sip coffee from the sidelines while you wait. A car makes an excellent (and comfortable!) urban hide.

3 FOCUS ON ONE SPECIES

Choosing one species to focus on is a great way to push yourself. Exploring different styles and techniques will create a more exciting collection of images that paints a fuller portrait of your subject. Pick a species that is accessible in your local patch, even if it is not the most glamorous of creatures. Remember, you're looking to create great images, not bad images of great animals.

Getting to know one species well will improve your fieldcraft skills, and telling its story will naturally suggest different images to try. Experiment with fast shutter speeds for a crisp action shot, or slower ones to create movement and depth. Play with scale, using macro imagery to explore texture, and wider compositions to show context. A long lens can open up other opportunities, such as photographing the increasing population of urban peregrines.

4 DON'T BE A FAIRWEATHER PHOTOGRAPHER

Shooting in the middle of the day while the light is bright is pleasant, but rarely produces the best images. Try getting up early, when there are fewer people around and the wildlife is bolder. Counteract low light levels by using a fast lens with a wide aperture of f4 or lower.

Getting out after dark brings other rewards. Many animals are more active at night, and newer cameras with high ISOs are making night photography more accessible than ever. Try using long exposures to enhance city lights, and an off-camera flash to highlight your subject. Even urban animals accustomed to noise and lights will be spooked by the combination of a bright flash and loud shutter, so keep your flash low and your ISO high. You could also consider opting for a mirrorless camera, to avoid the noisy 'clunk' of a DSLR.

Even the wet weather shouldn't keep you indoors. See puddles and rain as opportunities to get creative with reflection and texture, as well as documenting behaviours you wouldn't see on a dry day.

5 USE YOUR URBAN SETTING

In wildlife photography, it can be tempting to create images that crop out the city, creating an illusion of a wilderness that's untouched by humans. By going down this route you're in danger of editing the story out of your image, creating a shot that looks identical to thousands of others. Instead, try incorporating signage and street furniture into your images. Pointing your lens down a street can create interesting lines and bring distance into a crowded setting, while getting up on a bridge or tall building offers a totally different perspective.

If your composition is looking too busy, a shallow depth of field can de-clutter your image while retaining an urban atmosphere.

Get started

*MPB is the **world's largest online platform** for used photography and videography equipment. Each piece of kit is inspected carefully and comes with a **six-month warranty**. Here are some example setups:*

- **EOS 7D II camera** (£674, good condition)**; EF 100-400mm f/4.5-5.6 L IS USM lens** (£694, good condition)**; EF-S 60mm f/2.8 USM Macro lens** (£279, excellent condition)

A snip over £1,600, this is a budget-friendly Canon setup. The EOS 7D Mark II camera means you'll always be able to capture the subject with clarity.

- **D500 camera** (£1,009, excellent condition)**; AF-S 200-500mm f/5.6E ED VR lens** (£1,029, excellent condition)**; AF-S 105mm f/2.8G IF-ED VR Micro lens** (£439, good condition)

Stepping up in price at just under £2,500, this versatile used Nikon setup centres around the D500: a 21MP APS-C DSLR capable of shooting at up to 10 frames per second.

- **Alpha A9 camera** (£2,179, excellent condition)**; FE 70-200mm f/2.8 GM OSS lens** (£1,809, like new)**; FE 90mm f/2.8 Macro G OSS lens** (£744, like new)

This premium Sony setup won't leave much change from £5,000 but offers exceptional quality via a high-end mirrorless camera.

Prices correct at MPB.com at time of going to print

CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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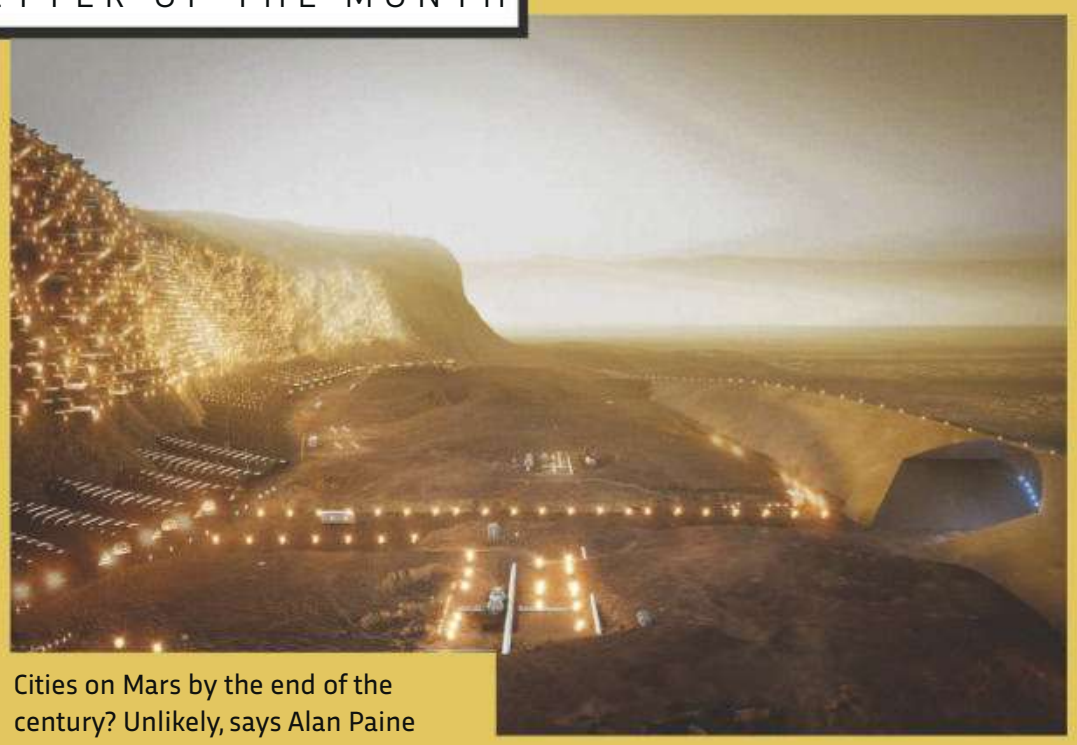
LETTER OF THE MONTH



Cities on Mars by the end of the century? Unlikely, says Alan Paine

Red Planet ready?

I find the idea of going to live on Mars interesting and have written some science fiction about it, but the idea of building five cities each with a population of 200,000 by the end of the century seems hopelessly ambitious (March, p44). Building the Channel Tunnel took the removal of 4.9 million cubic metres of material according to **eurotunnel.com** but Nüwa alone would require 187.5 million cubic metres of tunnels. Building such a city might be possible, but surely it would take centuries?

Alan Paine

I understand the scepticism. Indeed, there would be major technological challenges to overcome – not just the tunnelling. Muñez stated that to have it finished by the end of the century would require "the right financial resources and the right will." Even so, with detailed planning, perhaps the timescale would turn out to be over-optimistic. Conversely, perhaps the lower gravity on Mars would make excavation easier? As more studies take place, we will understand more about what it would take to build a city on Mars.

Dr Stuart Clark, *astronomer*

Hopping for some clarity...

I have a follow-up question for Luis Villazon, and the article that he wrote about birds hopping and walking (January, p85). Exactly how do birds hop? When humans hop, they usually do so purely vertically except when they are drifting because they lose their balance. Birds hop consistently to move. Sometimes hopping seems combined with flight, other times it doesn't. I think I just saw a bird hop from one planter to another – a distance of about a foot.

Tracy Crawford

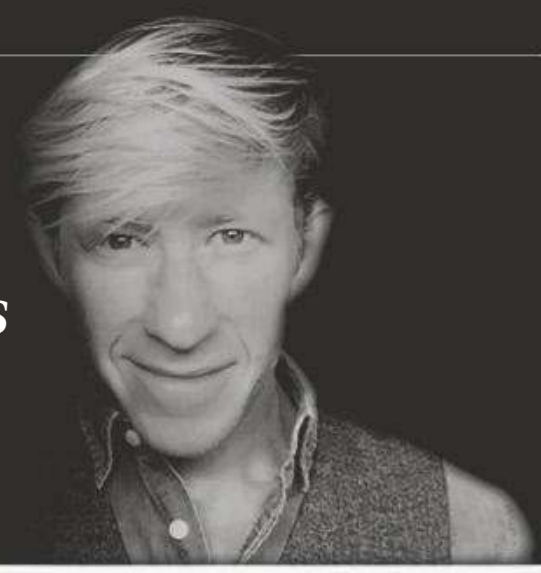
Birds hop in much the same way that we do – by contracting the leg muscles powerfully enough to propel themselves a short distance forward and up. Birds are much lighter than us and have long, springy tendons in their legs, so they can hop proportionately further distances, but the fundamental process is much the same.

Luis Villazon, *science and tech writer*

A bird's hopping skills, beautifully demonstrated by a blue tit

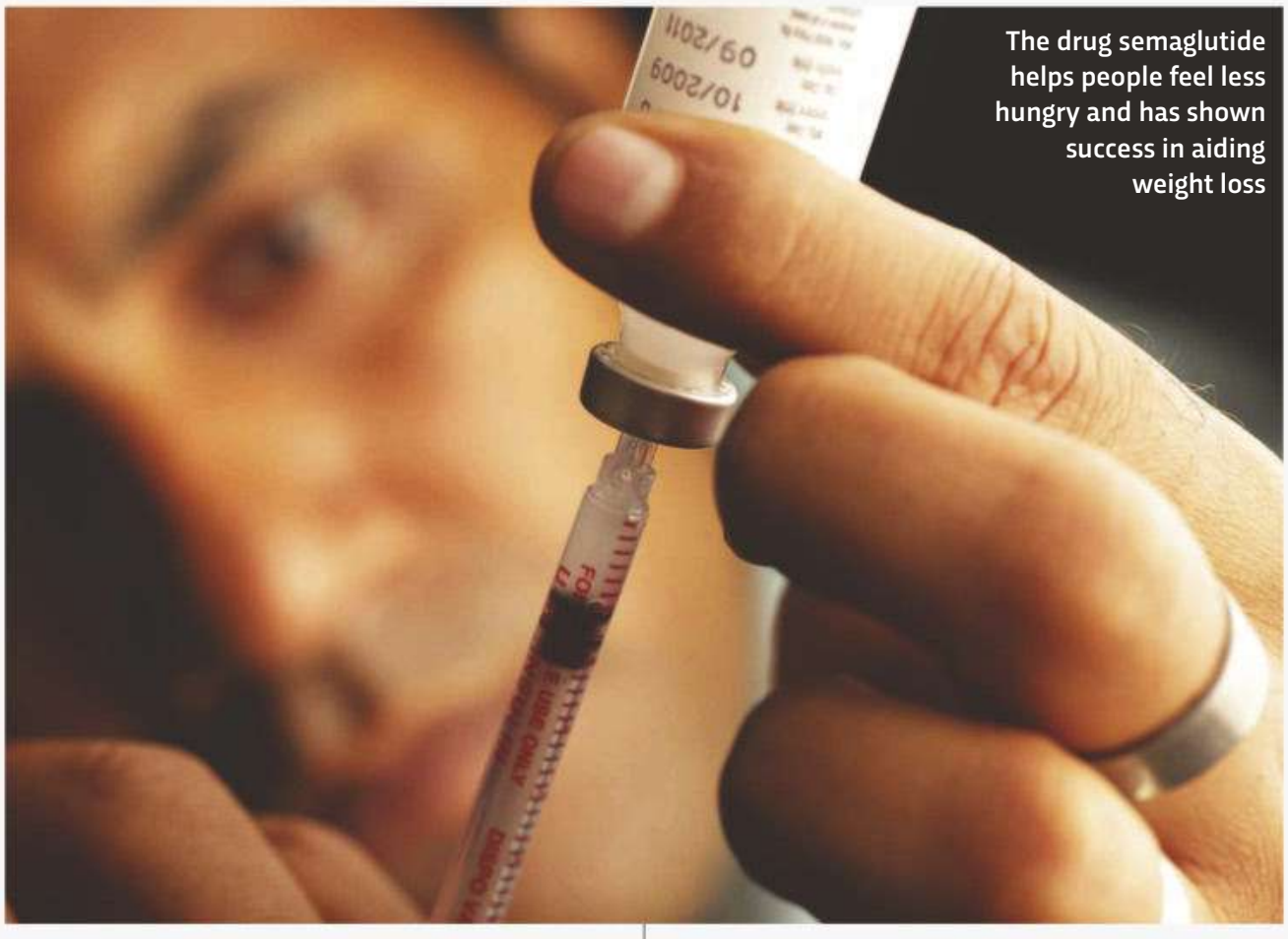
WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins two sets of **Innr Wi-Fi bulbs**, both colour and white editions. These LED smart lights connect directly to your router and won't just cut your energy bill, they'll also give you the choice of 16 million colours. You can set routines for your lights via the app, and even turn them on and off while you're out. **innr.com**



"WITHOUT PUTTING TOO STRONG A POINT ON IT, CONSIDER WAKEFULNESS AS LOW-LEVEL BIOCHEMICAL BRAIN DAMAGE, AND SLEEP AS SANITARY SALVATION"

DR MATTHEW WALKER, P52



The drug semaglutide helps people feel less hungry and has shown success in aiding weight loss

GETTY IMAGES X2, ABIBOOSTUDIO/SONET/GONZALO ROJAS/SEBASTIÁN RODRIGUEZ & VERÓNICA FLORIDO

Health injection

I read with interest your article about semaglutide (March, p34). I'm diabetic (type 2) and was prescribed semaglutide around two years ago, starting with a weekly injection of 0.5mg for six months, then increasing to 1mg.

The good points as far as I am concerned are that my weight has dropped from 69kg to 64kg, I am leaner and fitter than I used to be, my waist has gone from 35 inches to 32 inches and I feel a lot better. With me, it works by a sense of not having an appetite at all. I have little interest in food, but you have to be sensible here – I still have breakfast, lunch and dinner as it suits my diabetic diet. You still have your sense of smell, so food smells good and tastes like it always has done, but for me there's just a lack of interest. As long as you are sensible for the reasons above, for me I don't see any drawbacks.

Phil Bidwell

Pesky problem

In the November edition, in his article about food myths (p56), Prof Tim Spector refers to glyphosate as a pesticide. It is not. Glyphosate is herbicide, it kills any green plant. There is one heck of a difference between the two. I should know, I worked in agriculture for over 20 years. Pesticides can be specific and so can herbicides, but glyphosate is a 'broad spectrum' herbicide and kills any plants.

Colin Lang

According to the UK's Health and Safety Executive, pesticides are defined as something that can control pests, weeds and diseases, and includes insecticides, fungicides and herbicides. But yes, there is a difference in day-to-day use, with pesticides being used to get rid of pests, and herbicides to eliminate nuisance plants.

Alice Lipscombe-Southwell, *managing editor*

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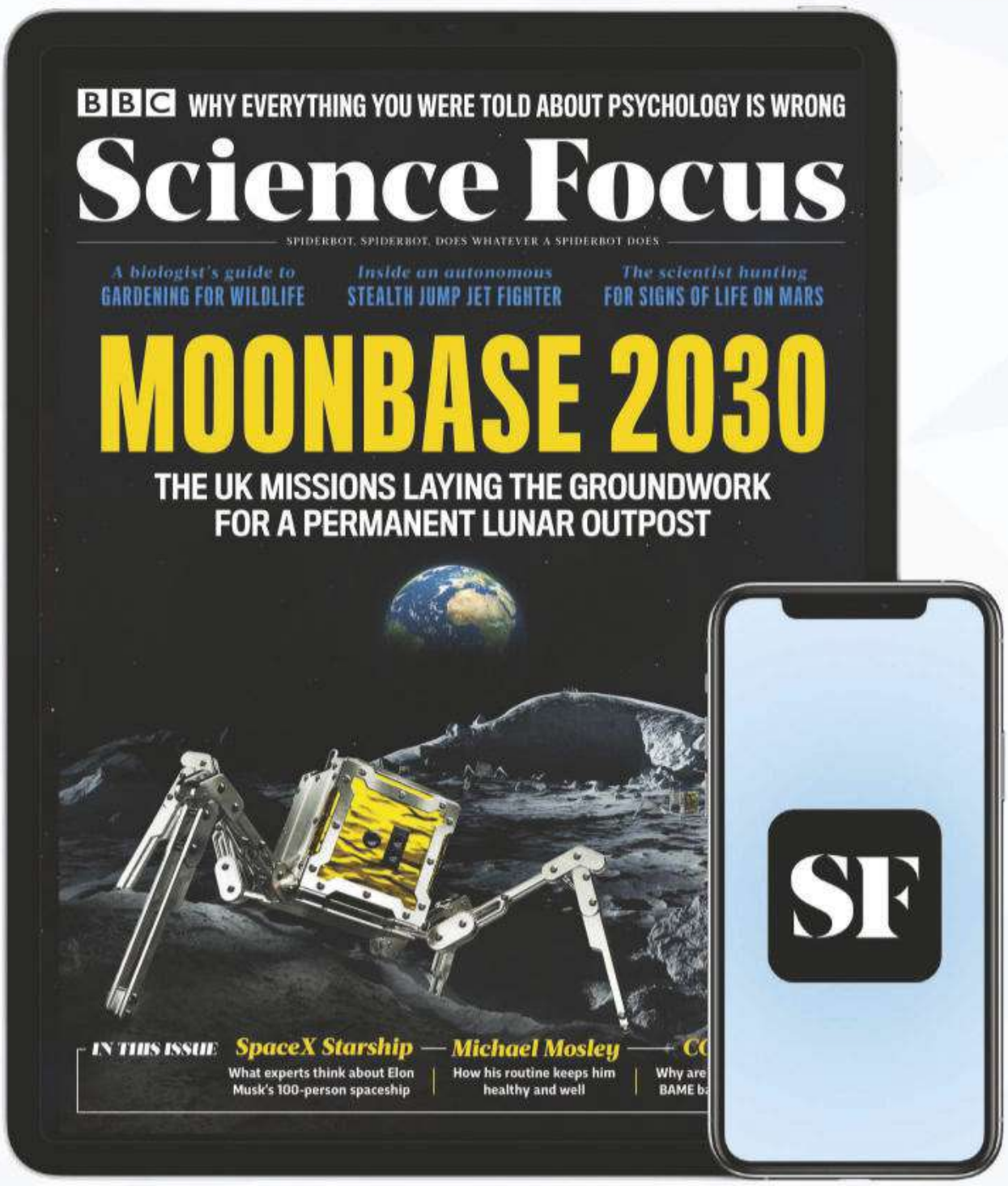
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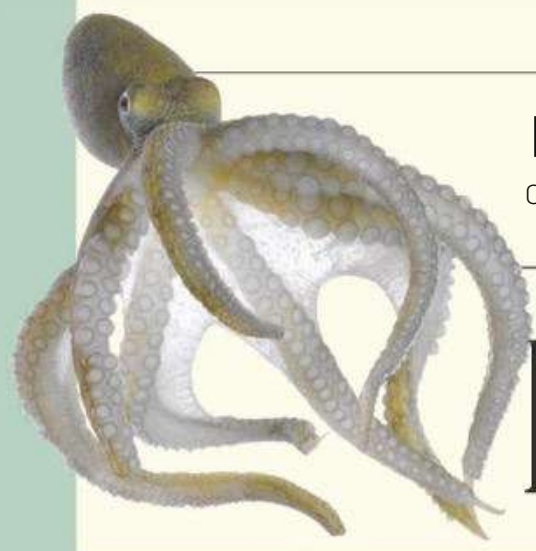

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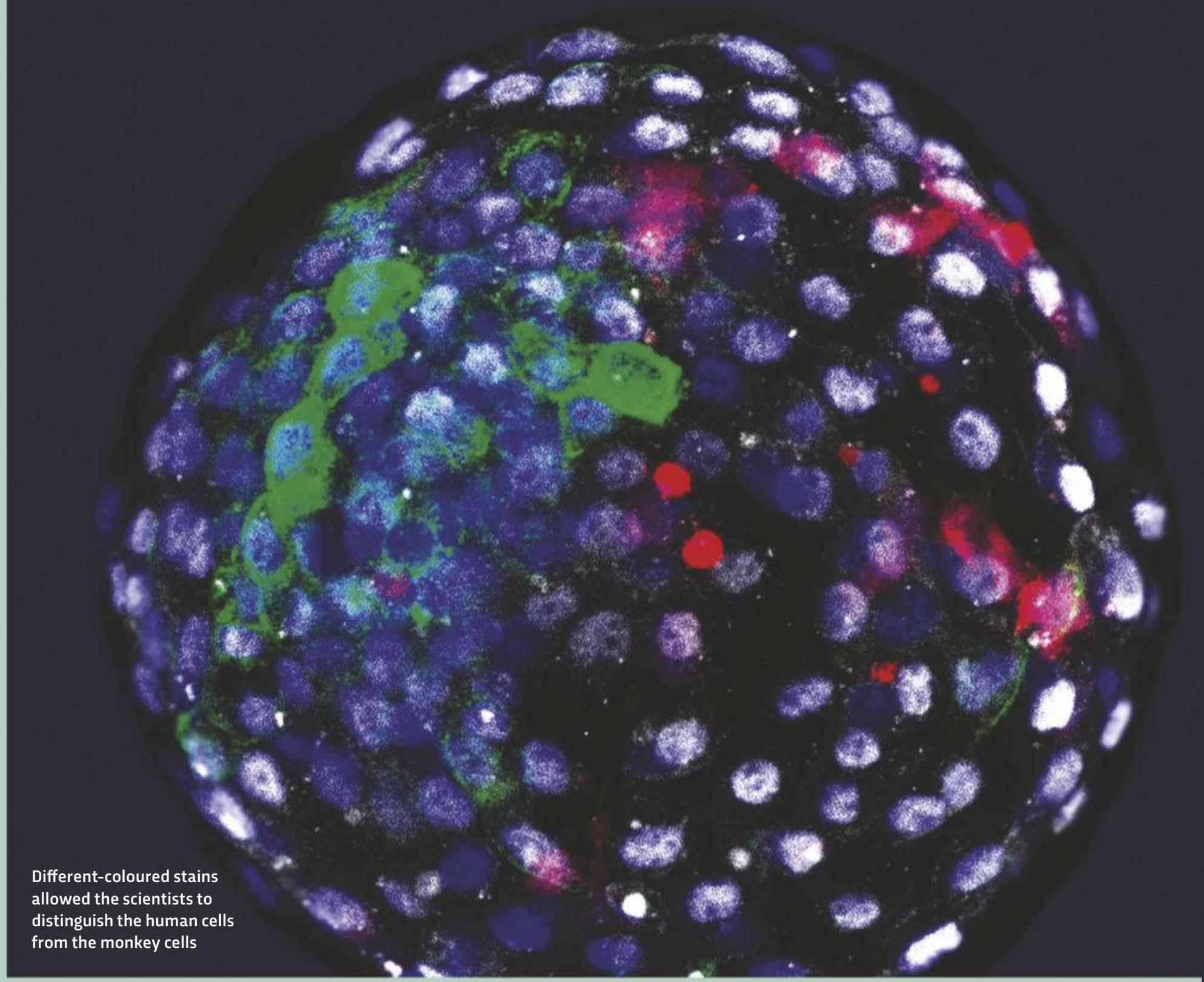
CHEERS BEERS!
Waste products from beer turned into food p20

BRING A JACKET...
New Martian weather reports suggest it's a bit nippy p21

DISCOVERIES

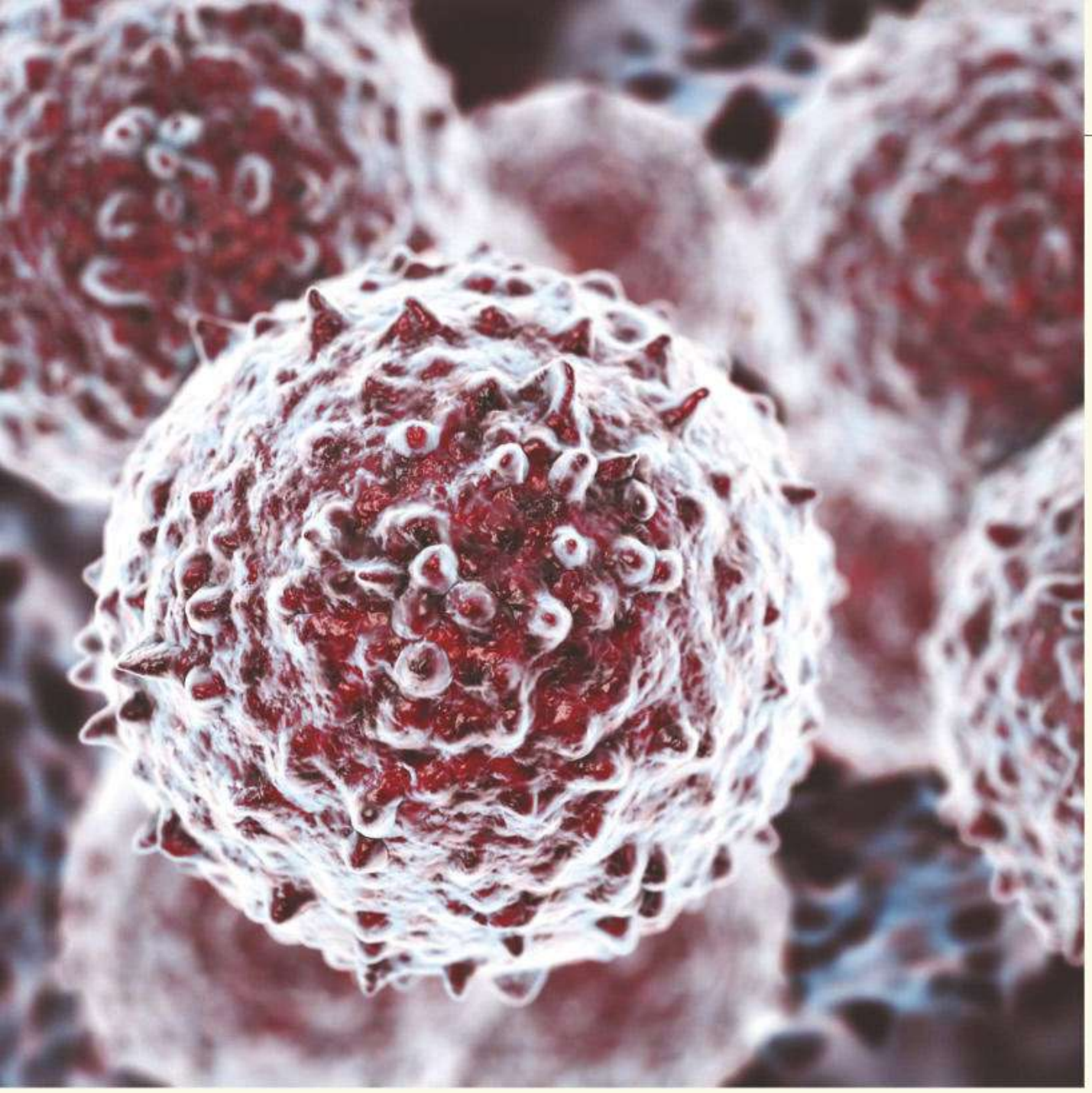
SCIENTISTS CREATE HUMAN-MONKEY EMBRYOS



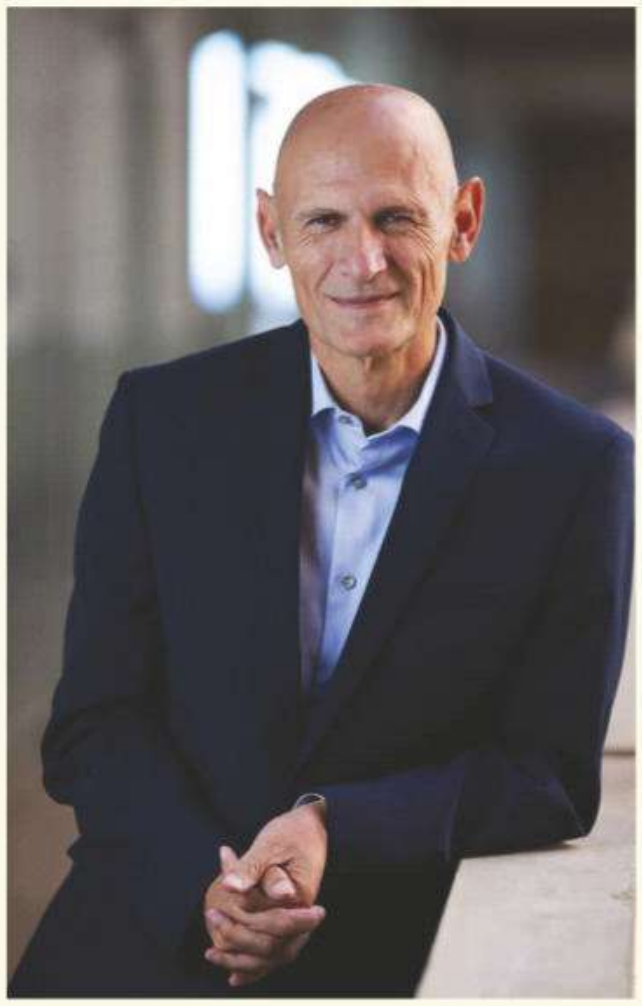
WEIZHI JI/KUNMING UNIVERSITY OF SCIENCE AND TECHNOLOGY

Different-coloured stains allowed the scientists to distinguish the human cells from the monkey cells

Toothy trouble Scientists have found out the cause of cold-sensitive teeth p22 **Bunny hops** By studying handstanding rabbits that can't bounce at all, scientists have revealed why some animals hop p23 **Always hungry?** It could be in your blood p26



LEFT Human stem cells, as seen in this image, were injected into the monkey embryos



BELOW Senior author Prof Juan Carlos Izpisua Belmonte, from the Salk Institute

Creating an organism that contains human cells and those of another species is deeply complex, with ethical considerations as mind-boggling as the biology. A team of scientists has, however, made a major breakthrough in the field, with potentially huge ramifications for the study of human evolution, disease, drug-testing and ageing.

Researchers at the Salk Institute in San Diego injected human stem cells into non-human primate embryos, which then survived in the laboratory for up to 20 days. Not only did they survive for longer than previous experiments, but researchers identified 'communication pathways' that may hold clues about how human cells integrate with non-human cells in chimera organisms.

"As we are unable to conduct certain types of experiments in humans, it is essential that we have better models to more accurately study and understand human biology and disease," said senior author Prof Juan Carlos Izpisua Belmonte, from the Gene Expression Laboratory at the Salk Institute. "An important goal of experimental biology is the development of model systems

"It is essential that we have better models to accurately study human biology and disease"

that allow for the study of human diseases under in vivo conditions."

Interspecies chimeras have been created in laboratories since the 1970s but those involving human cells have never come this far. As well as providing a tool for studying diseases and evaluating new drugs for treating them, these chimeric models could also potentially be used to grow tissue for organ transplants.

The team at Salk created crab-eating macaque embryos outside of an animal's body, building on work by collaborators in China. After six days, they injected 25 human stem cells into each of the embryos. The embryos slowly died off but scientists were amazed that the percentage of human cells remained high as the embryos grew.

"Historically, the generation of human-animal chimeras has suffered from low efficiency and integration of human cells into the host species," Izpisua Belmonte said. "Generation of a chimera between human and non-human primate, a species more closely related to humans along the evolutionary timeline than all previously used species, will allow us to gain better insight into whether there are evolutionarily imposed barriers to chimera generation and if there are any means by which we can overcome them."

The breakthrough is sure to reignite debate around the ethics of creating human/non-human chimeras, a point that Izpisua Belmonte himself addressed. "It is our responsibility as scientists to conduct our research thoughtfully, following all the ethical, legal, and social guidelines in place," he said, adding that before beginning this work, "ethical consultations and reviews were performed both at the institutional level and via outreach to non-affiliated bioethicists."

ENVIRONMENTALLY FRIENDLY SHOPPERS

Choosing eco-friendly products can make us appear to be more attractive, a study at the University of Groningen in The Netherlands has found. The effect is possibly due to buyers of green products being viewed as more generous, they say. Now, where do they sell sweaters knitted from mung beans?

PETS

Attention all good boys and girls! Carnivac-Cov, a COVID-19 vaccine developed in Russia, was proven to generate antibodies in both dogs and cats.

Good month

Bad month

LATE-NIGHT SNACKERS

Looks like we'd better put a lock on the biscuit tin. Eating snacks at night can make people less helpful and more withdrawn the next day at work, a study at North Carolina State University has found.

WINE SNOBS

Next time you have guests over for dinner, don't bother spending big bucks on the Bolly. Researchers at the University of Basel, Switzerland have found that people rate cheap wine as tasting better if they are told it is expensive. We won't tell if you don't.

SCIENCE PHOTO LIBRARY, SALK INSTITUTE, JORGE BLANCO ILLUSTRATIONS: KYLE SMART

PALAEONTOLOGY

'One who causes fear': newly discovered dino was a top predator

The abelisaurid family were all good hunters, but *Llukalkan aliocranianus*'s hearing set it apart from its relatives

A species of dinosaur newly discovered in Patagonia, Argentina, has been given a name meaning 'One who causes fear' in the indigenous Mapuche language due to its deadly hunting abilities.

With its sharp teeth, long claws and powerful bite, *Llukalkan aliocranianus* is as formidable as other species in its family, the abelisaurids. It moved quickly on its powerful hind legs, and had a keen sense of smell.

Its short skull had rough bones, so in life it probably had lumps and ridges on its head like iguanas or Gila monsters. But what really sets it apart is its remarkable sense of hearing.

Palaeontologists in Argentina found fossil remains of the dinosaur at a site called the Bajo de la Carpa Formation, only 700m from the remains of a closely related species named *Viavenator exxoni*.

"This is a particularly important discovery because it suggests that the diversity and abundance of abelisaurids were remarkable, not only across Patagonia, but also in more local areas during the dinosaurs' twilight period," says lead author Dr Federico Gianechini, a palaeontologist at the National University of San Luis, Argentina.

The *L. aliocranianus* specimen was superbly preserved, including an uncrushed cranium. In the skull, the researchers found an air-filled sinus in the middle ear that no other abelisaurids have.

What this means is that the dinosaur most likely had better hearing than its abelisaurid relatives – like that of a modern crocodile, says study co-author Dr Ariel Méndez from the Instituto Patagónico de Geología y Paleontología. "This finding implies a different hearing adaptation from other abelisaurids, and likely a keener sense of hearing," he said.

L. aliocranianus lived only a few million years before the dinosaurs went extinct. "These dinosaurs were still trying out new evolutionary pathways and rapidly diversifying right before they died out completely," Méndez said.

Clever girl: Fossil evidence suggested *Llukalkan aliocranianus* was a keen hunter

ZOOLOGY

Octopuses have sleep stages like humans – and may even dream

True, you may never see an octopus slip into some pyjamas or snuggle under a duvet, but research has discovered that the cephalopods closely mirror human sleep stages while snoozing.

A new study from Brazil's University of Rio Grande do Norte has revealed that the eight-limbed creatures have two major alternating sleep states: an 'active sleep' stage and a 'quiet sleep' stage. When observing octopuses sleeping in a lab setting, researchers found that during 'quiet sleep', the animals were motionless, with their pupils contracted. However, during 'active sleep', they changed their skin colour and texture, and – akin to humans during rapid eye movement (REM) sleep – moved their eyes and experienced muscle twitches. Although it could not be confirmed, these findings indicate that octopuses may be able to dream in their sleep.

"Our results suggest that during 'active sleep' the octopus might experience a state analogous to REM sleep, which is the state during which humans dream the most," said lead researcher Sylvia Medeiros. "If octopuses indeed dream, it is unlikely that they experience complex symbolic plots like we do. 'Active sleep' in the octopus has a very short duration – typically from a few seconds to one minute. If during this state there is any dreaming going on, it should be more like small video clips, or even gifs."

Whether octopuses dream or not, the study raises major questions about the nature of sleep. As humans and octopuses evolved almost independently (their lineages diverged around 500 million years ago), the similarity between the sleep stages asks why both exhibit this behaviour.

"If in fact two different sleep states evolved twice independently in vertebrates and invertebrates, what are the essential evolutionary pressures shaping this physiological process? The independent evolution in cephalopods of an 'active sleep' analogous to vertebrate REM sleep may reflect an emerging property common to centralised nervous systems that reach a certain complexity," Medeiros said.

SYLVIA L S MADEIROS ILLUSTRATION: ACUTE GRAPHICS

MARS

Scientists have measured the core of Mars, and found something unexpected

For the first time, scientists have directly measured the core of another planet. NASA's InSight mission on Mars has discovered the Red Planet's core is bigger than expected.

Instruments on the craft have listened to seismic energy deep within the planet, and have suggested a core measurement of between 1,810km and 1,860km in diameter, roughly half the size of Earth's core. It's larger than some predictions, which means the Martian core is less dense than previous estimates, probably due to the presence of lighter elements such as oxygen.

The measurements, which were taken with a seismometer, have not yet been published, but were reported at a virtual gathering of the Lunar and Planetary Science Conference.

"A seismometer is like a very sensitive ear pressed against the ground, listening for energetic events in the interior of a planet. On Earth, these are usually earthquakes. InSight has detected hundreds of seismic events in the first Martian year of its mission," said Divya Persaud, a planetary scientist at UCL, who was not involved in the research. "On Earth, when an earthquake releases a lot of energy, these waves of energy travel quickly throughout the interior of the planet and bounce off different materials, like magma, or the boundaries between layers of different types of rock. They also slow down in some materials or speed up in others."

By measuring the strength of these signals, and how they interact with material underground, scientists can detect the internal structure of the planet. The InSight team used the same technique on Mars.

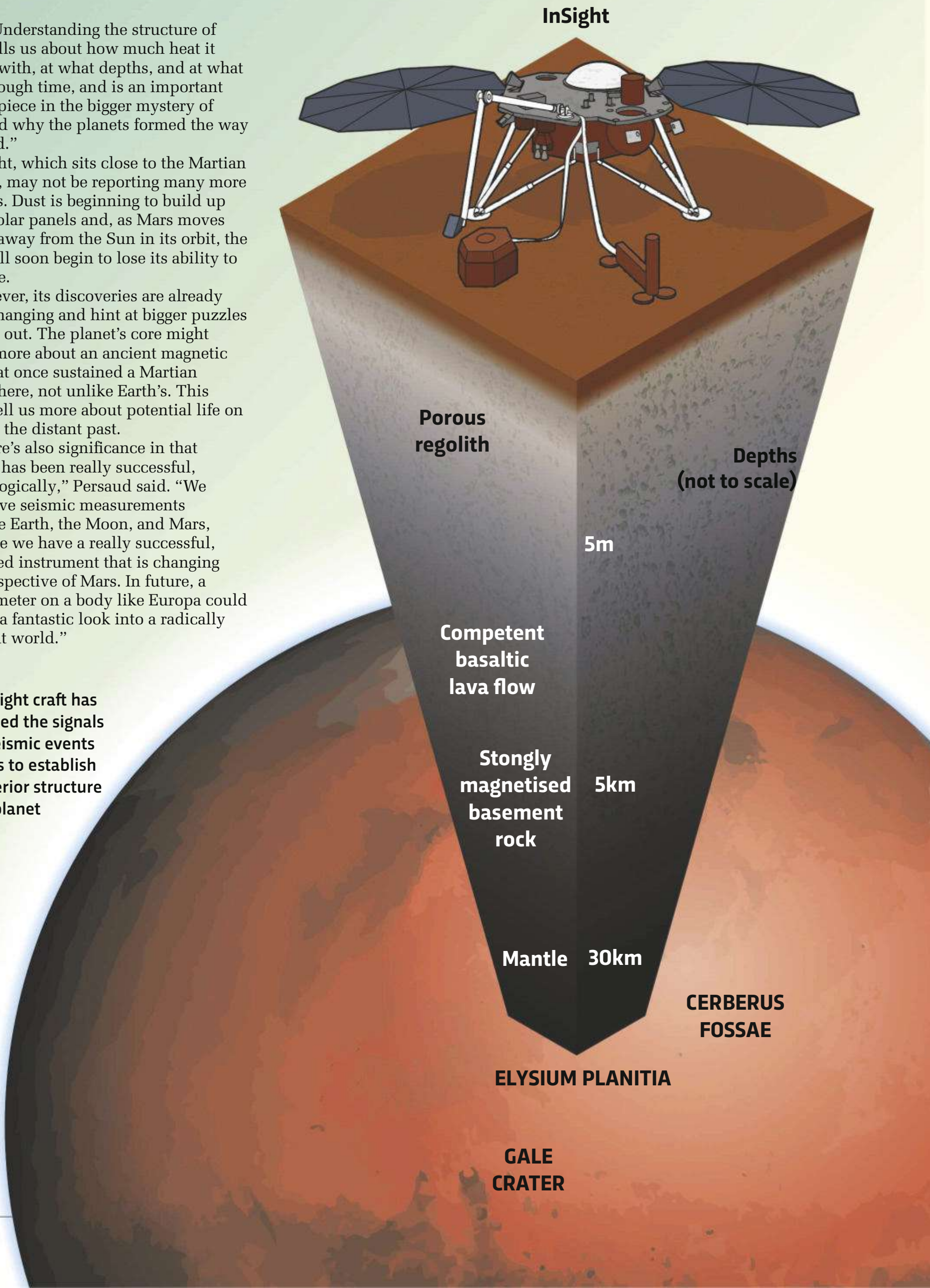
Persaud is intrigued that the core isn't as dense as expected, because it may lead to new understandings about how planets and the wider Solar System evolved. "Cores also tell us about energy in the Solar System over time, not just for Mars but all of the terrestrial planets which formed at the same time but in very different ways from each other," she

said. "Understanding the structure of Mars tells us about how much heat it started with, at what depths, and at what rate through time, and is an important puzzle piece in the bigger mystery of how and why the planets formed the way they did."

InSight, which sits close to the Martian equator, may not be reporting many more findings. Dust is beginning to build up on its solar panels and, as Mars moves farther away from the Sun in its orbit, the craft will soon begin to lose its ability to recharge.

However, its discoveries are already game-changing and hint at bigger puzzles to work out. The planet's core might tell us more about an ancient magnetic field that once sustained a Martian atmosphere, not unlike Earth's. This could tell us more about potential life on Mars in the distant past.

"There's also significance in that InSight has been really successful, technologically," Persaud said. "We only have seismic measurements from the Earth, the Moon, and Mars, and here we have a really successful, advanced instrument that is changing our perspective of Mars. In future, a seismometer on a body like Europa could give us a fantastic look into a radically different world."



The InSight craft has measured the signals from seismic events on Mars to establish the interior structure of the planet

In numbers

7

The percentage of UK native woodland that is in good condition, according to the Woodland Trust. While woodland cover is increasing, wildlife within it is decreasing, the charity says.

4

The number of trees felled per year in developing countries as a result of one average Westerner's consumption of chocolate, coffee, beef and other imported goods, as calculated by researchers in Kyoto, Japan.

7

The percentage of global deaths that are linked to a lack of physical activity, according to a study by researchers at the Pennington Biomedical Research Center.

Spent grain could have a new lease of life

FOOD

Cheers! Beer-brewing waste can be turned into food and fuel with a little help from friendly microbes

Whether your go-to tipple is a crisp, Bohemian-style pilsner, a dark and roasty stout, or a dank, American-style IPA, all styles of beer have one thing in common: producing them creates mounds and mounds of leftover barley and other grains.

Traditionally, this by-product has been used in cattle feed or simply put into landfill. But now, researchers at Virginia Polytechnic and State University (Virginia Tech) have developed an innovative method of extracting nutrients and fibre from spent grain for use in new food sources and biofuels.

Spent grain accounts for around 85 per cent of the waste material produced from brewing. It is made up of 30 per cent protein and 70 per cent fibre. While suitable for consumption by cows, the high fibre content makes it difficult for humans to digest.

"Spent grain has a very high percentage of protein compared to other agricultural waste, so our goal was to find a novel way to extract and use it," said Virginia Tech graduate student Yanhong He.

In order to figure out a method of turning leftover grain into something more useful, the team partnered with local breweries. They developed a method of separating the grain into a protein concentrate and a fibre-rich powder by treating it with alcalase, a commonly available enzyme, and then sieving it.

Through this method they were able to extract more than 80 per cent of the protein from the grain. Initially, they proposed that this could be used as a cheap, sustainable food for use in shrimp farms. But now, given the rise in the number of people switching to a plant-based diet, they are looking into using it as an alternative protein source in various foods for human consumption.

In a separate project, another team from Virginia Tech has developed a method of treating the fibre with *Bacillus licheniformis*, a species of bacteria recently discovered in a spring in Yellowstone National Park. By treating the fibre with the bacteria, it is possible to convert various sugars within it to 2,3-butanediol, a compound that is used to make many products, such as biofuels, synthetic rubber, and materials for creating plastics.

SHUTTERSTOCK, NASA/JPL

MARS

The Perseverance rover is sending weather reports back from Mars

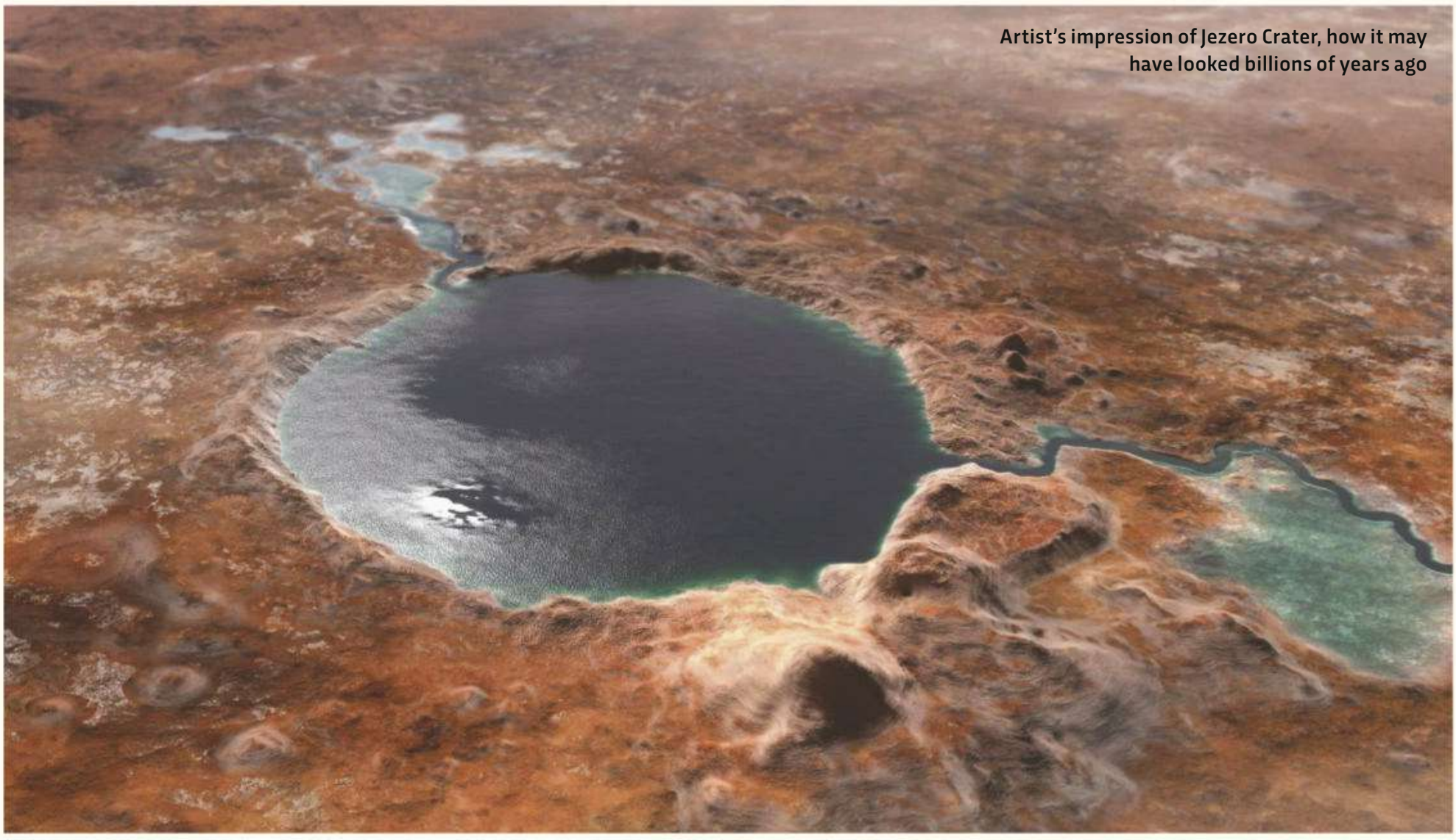
And now for the weather… from Mars. NASA scientists have analysed the first meteorological reports recorded by its Perseverance rover on the Red Planet. The short version: if you're planning to spend some time at the Jezero Crater, you'll need a coat (yes, and a spacesuit) because it's -20°C on a warm day.

The rover, which landed in February, is equipped with a planet-hopping weather station called the Mars Environmental Dynamics Analyzer (MEDA). Its sensors record wind speed and direction, air and ground temperature, as well as pressure, humidity and radiation. Its first measurements were taken the day after it landed and MEDA wakes itself up every hour to take fresh readings. The forecast: cold with strong gusts and an ever-present risk of a dust storm. Perseverance has so far recorded lows of -83°C and wind speeds of 35km/h (22mph). Over the next year, it will give NASA scientists useful information such as temperature cycles, dust patterns, solar radiation readings and cloud formations.

Just like we check our weather apps before heading out for a walk, the MEDA data will help engineers plan the rover's movements and experiments, including flights of the Ingenuity Mars Helicopter. It will also be important for future crewed missions to the Red Planet – and not just to give astronauts something to talk about. Understanding how conditions fluctuate over time will inform things like the kinds of habitat required for future Mars bases.

"We're very excited to see MEDA working well," said Manuel de la Torre Juárez, deputy principal investigator for MEDA. "MEDA's reports will provide a better picture of the environment near the surface. Data from MEDA and other instrument experiments will reveal more pieces of the puzzles on Mars and help prepare for human exploration. We hope that its data will help make our designs stronger and our missions safer."

It's not the first time scientists have received weather reports from Mars. Two other missions – Curiosity and InSight – have sent home meteorological data from their landing sites. Together with MEDA's forecasts, as well as satellite and telescope data, these are helping scientists build a complete picture of weather patterns on the Red Planet.



Artist's impression of Jezero Crater, how it may have looked billions of years ago

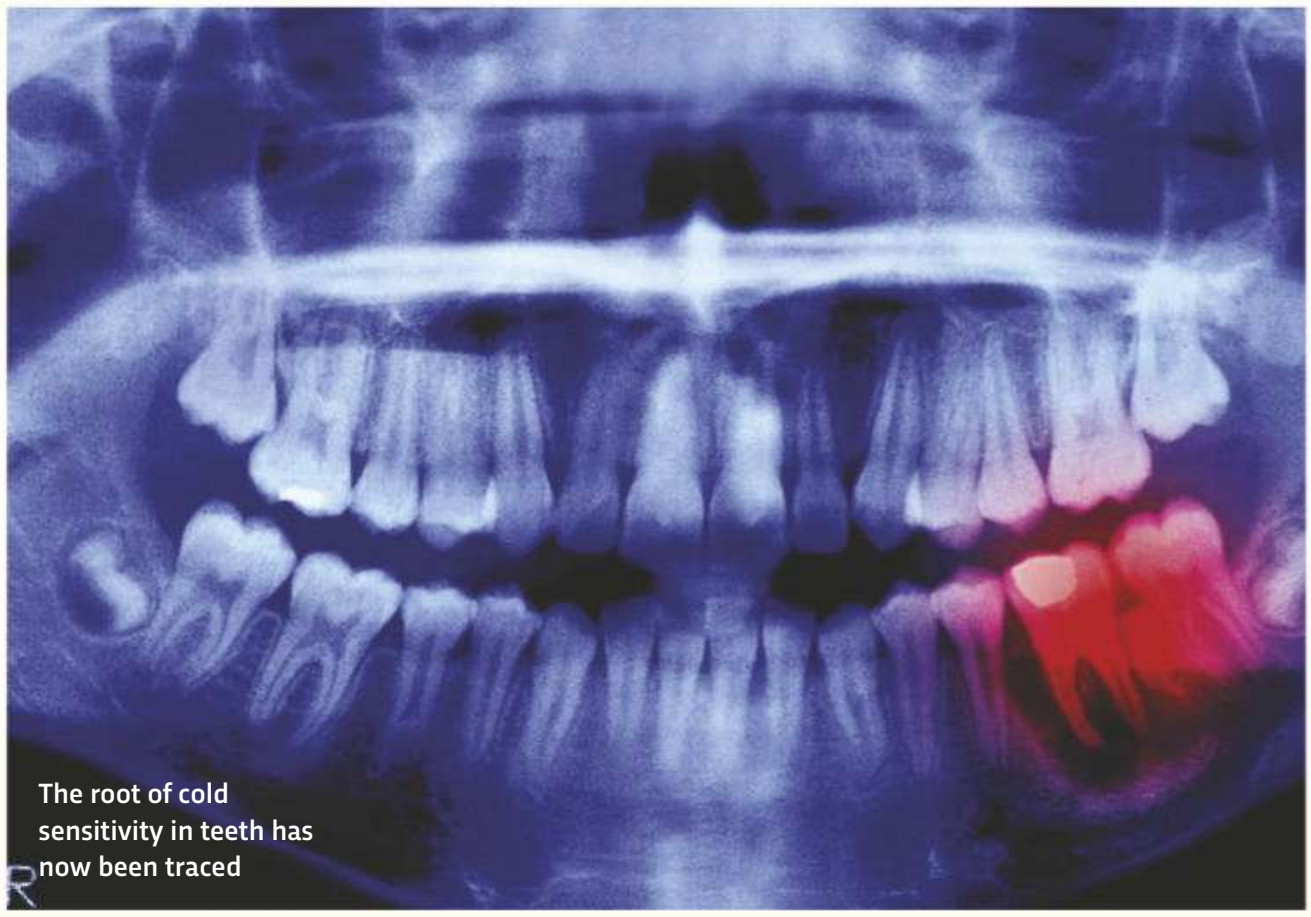
They did what?

Scientists implanted false memories... then removed them

WHAT DID THEY DO?
In a study that would make Christopher Nolan proud, researchers from the UK and Germany implanted four memories into 52 volunteers. Two memories were real, and two were false memories that didn't happen, but were plausible. For example, getting lost, running away or being involved in a car accident. The participants' parents helped with the study, and told them that the events had definitely happened.

WHAT DID THEY FIND?
After three sessions in which the participants were asked to recall the memories, 40 per cent of them believed the false stories to be true. Then, by explaining how false memories can arise externally from other family members' stories or photographs, or simply by repeatedly being asked to recall them, the researchers were able to make 74 per cent of the participants who had previously believed the false memories reject them.

WHY DID THEY DO THAT?
As false memories given as evidence in a courtroom can lead to wrongful convictions, learning more about how memories are created, identified and reversed could be a 'gamechanger', the researchers say.



The root of cold sensitivity in teeth has now been traced

MEDICINE

Sensitive teeth? Scientists discover why cold drinks and ice cream can be so painful

We've all been there. An enthusiastic chomp of an ice lolly triggers a sharp, intense pain in your teeth that is mercifully rare outside the dentist's chair. Now, scientists think they've discovered what causes the grim sensation, and how teeth feel the cold in the first place.

A new study carried out at the Howard Hughes Medical Institute (HHMI) in the US revealed that certain tooth cells contain cold-sensitive proteins that detect drops in temperature and then sound the alarm to the brain, triggering a wince-inducing jolt.

"It's a unique kind of pain," said Dr David Clapham, vice president and chief scientific officer of the HHMI. "It's just excruciating."

Clapham, together with an international team of scientists, traced the source of the pain back to an ion channel called TRPC5 that they first discovered 15 years ago. Ion channels are proteins that create pores in the membranes of every cell in our bodies. These act like molecular gateways, opening or slamming shut when they detect the presence of certain chemicals, electrical signals or changes in temperature. When they open, ions (charged particles) flood into the cell, creating an electrical pulse that travels between cells. It's one of the body's mechanisms for quickly sending information, and underpins a number of essential bodily functions.

In the new research, the team traced the TRPC5 ion channel back to a specific kind of cell called odontoblasts, which are found in the teeth. The cold-sensitive protein kicks off when exposed to a drop in temperature, triggering a jolt of pain.

It's also a good reason to brush your teeth properly. The team found that TRPC5 is more prevalent in teeth that have cavities, explaining why tooth decay can increase our sensitivity to cold food and drinks. It's thought that 2.4 billion people have untreated cavities in their teeth. The enamel on our teeth is the hardest substance in our bodies, but bacteria and acid cause it to erode.

Clapham's team hopes the research will lead to new treatments for sensitive teeth.

CARNEIRO M ET AL/PLOS GENETICS, GETTY IMAGES ILLUSTRATION: KYLE SMART

BIOLOGY

Rabbits that do handstands reveal why some animals can hop

The Alfort jumper rabbit has a mutation in a gene known as RORB that prevents it from hopping like most other breeds

Researchers at Universidade do Porto in Portugal and Uppsala University in Sweden have found the gene behind hopping animals' bouncing gait – by studying a breed of rabbit that doesn't hop at all.

The sauteur d'Alfort, also known as the Alfort jumper rabbit, has a rather acrobatic way of moving. Over short distances, particularly when it's moving slowly, the rabbit will walk more or less as normal, though its back feet will hit the floor one after the other, rather than both at the same time. But when it wants to travel further or faster, it lifts its back feet above its head in an agile handstand, and walks on its front paws. So why doesn't this breed of rabbit bounce, like most other bunnies?

Earlier research on the breed in 1943 showed that this strange locomotion was due to a recessive gene, and was not a learned behaviour. So the team wanted to find out what gene was responsible for the difference.

The researchers bred Alfort jumper rabbits with another breed and compared their offspring's genomes and jumping abilities. They found that the ability to hop correctly depended on whether or not the rabbit had a functioning copy of the gene called 'RAR-related orphan receptor beta', or RORB. The rabbits with a specific mutation in this gene couldn't jump, and instead walked on their front paws.

The RORB gene encodes for a protein found in many places in the rabbit nervous system. Rabbits with the mutation had fewer neurons in their spinal cord that produced this protein.

Previous studies have looked at the impact of the RORB gene in other animals. A 2017 study published in the journal *Neuron* showed that mice without the gene walked with a high-legged step described as a 'duck gait'.

The team say that the study also improves our knowledge of the different ways that vertebrates can walk.

When it wants to travel further or faster, the Alfort jumper rabbit lifts its back feet above its head in a handstand

PHOTOGRAPHY

Bird Photographer of the Year 2021 finalists announced

Now in its sixth year, the Bird Photographer of the Year competition saw more than 22,000 entries from 73 different countries all competing for the £5,000 grand prize. The winners of the competition will be announced on 1 September 2021. In the meantime, you can see the full lineup of finalists at **birdpoty.com/news/bpoty2021-finalists**

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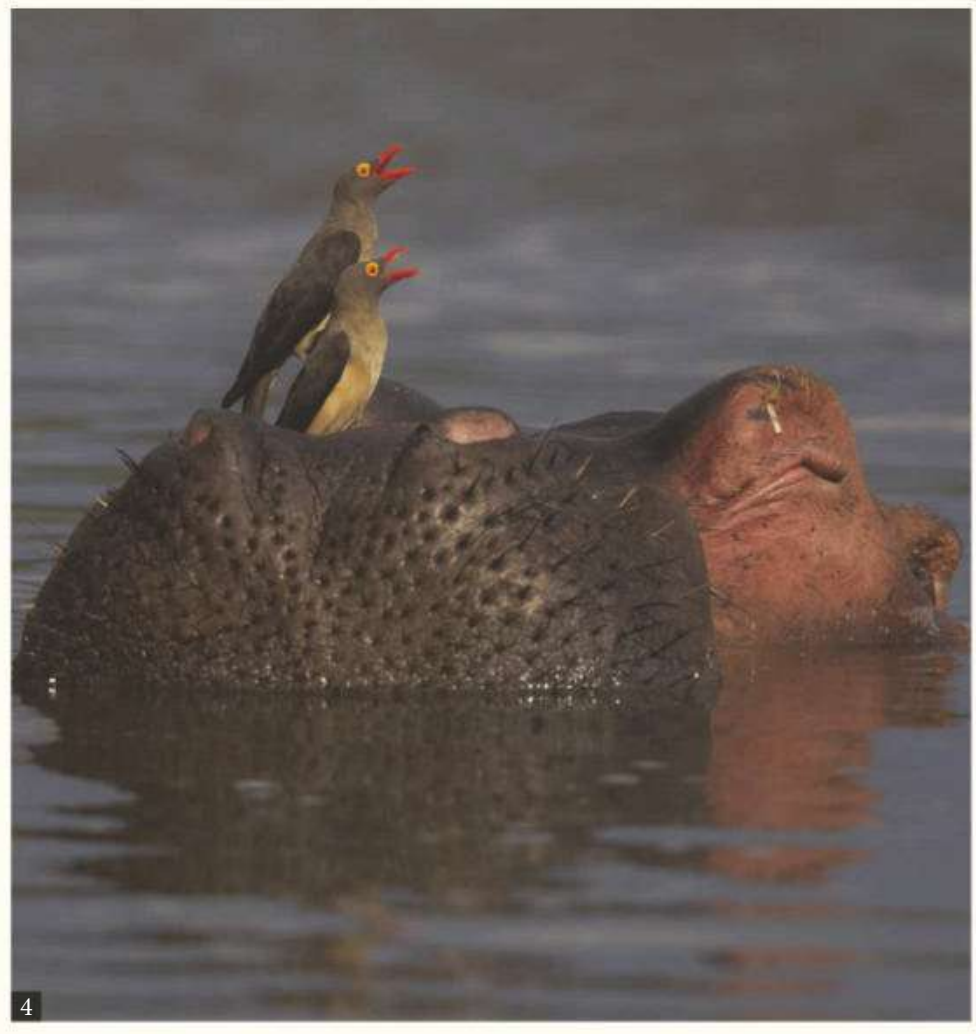
FAHAD ALENEZI, JAMES WILCOX, DAVID WHITE, BRIAN MATTHEWS, DANIELA ANGER



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1. American oystercatchers
by James Wilcox
This shot, taken at Lido Beach in New York, shows a pair of oystercatchers out for a morning forage. The chick is still heavily reliant on its parents for food as its beak hasn't developed the strength to open the shells of molluscs and crustaceans.

2. Swallow
by David White
Swallows often build their nests in the eaves and rafters of farm buildings. These birds return every spring to nest in this stable in Bourne, Lincolnshire.

3. White-tailed sea eagle
by Fahad Alenezi
In winter, food can be in short supply in northern latitudes, leading many animals to take risks. In this shot, taken in Rausu, Japan, a white-tailed sea eagle swoops down at a red fox that had ventured too close to where it was feeding.

4. Red-billed oxpeckers
by Daniela Anger
These little birds in Zambia's South Luangwa National Park have evolved a symbiotic relationship with hippos: the oxpeckers feed on external parasites and the hippos benefit from the hygienic makeover.

5. European shag
by Brian Matthews
This peckish shag in the UK's Farne Islands dives down its mother's throat before she has a chance to regurgitate her catch.

DR SARAH BERRY
Nutritional scientist

Horizons

Hungry all of the time? It could be in your blood

Researchers working on the largest in-depth nutrition study in the world have found that some of us experience big dips in blood sugar levels after eating, and it makes us hungrier, sooner

GETTY IMAGES

WAS THERE A PARTICULAR REASON THAT BREAKFAST WAS THE MEAL YOU CHOSE TO FOCUS ON FOR THIS STUDY?

For the PREDICT study we had two components. One was a very tightly controlled clinic day where people were attending our clinic in the UK at St Thomas's Hospital, or the clinic in the USA at Massachusetts General Hospital in Boston. And we gave them what we call a 'metabolic challenge meal' – a standardised, high-fat, high-carb meal for breakfast, in the form of a muffin and a milkshake. Then we gave them a standardised lunch to really stress their systems so we could start to differentiate people's responses.

Then they entered a two-week at-home phase where they were fitted with various wearable technology, such as a continuous glucose monitor. During the at-home phase we provided them with standardised breakfasts with different macronutrient compositions for the whole two weeks. They differed each day in terms of the fat, protein, carbohydrate and fibre. By giving it to them as a breakfast, it meant that everyone came to them standardised, as they'd all fasted overnight. We asked them to avoid exercise because we know exercise can modulate your glycemic response. Then, after three hours they were allowed to eat freely, whichever meals they wanted, and we call this *ad libitum*. This way we could also look in a very real-life context, as well as in this tightly controlled context.

WHAT DID YOU FIND?

The key finding from our overall PREDICT programme was that there's huge variability in how people respond to food. We know that humans are very complicated in how we metabolise food, and we know that food is very complicated, in terms of the thousands of chemicals in it and the complexity of their structure. And so, because of that, what we saw was that there was a nearly 10-fold difference in how I might respond versus how you might respond to exactly the same food in a tightly controlled setting.

What we also saw was that it wasn't all about what we ate that determines how we respond to foods, and it also wasn't all in our genes. About 70 per cent of our participants were identical twins so we could tease apart the genetic contribution to this variability in responses versus the non-genetic. And we found that genetics actually played a small role and that wasn't what was really important. Yes, what we ate was obviously important, but equally important was how we ate it – the time of day, when we took our exercise, how much sleep we'd had the night before, and the preceding meal as well.

"The key finding from our overall PREDICT programme was that there's huge variability in how people respond to food"

Your metabolism's response to this breakfast is likely to be different from mine

Because we used continuous glucose monitoring from a sensor that the participants wore on their arm, we were able to move beyond looking at typical features of the glucose response after a meal. What we found was that there were some people that in the two to four hours after consuming a meal had quite a dip in their glucose below their normal baseline level and some people who didn't. We found that if we separated people according to whether they were 'big dippers' or 'little dippers', it impacted how hungry they were. People that have bigger dips were more hungry. On average they consumed their next meal about 30 minutes before people that were little dippers. They also consumed more calories at their next meal.

What I find particularly interesting as a nutritionist is that people who had a bigger dip three to four hours after eating had consumed about 300 more calories over a 24-hour period compared to little dippers. I think this is really important because what we know from many years of research is that, yes, you might consume less at a subsequent meal if you've have a particularly satiating meal, but typically over a 24-hour period it kind of balances itself out. And we also found that it impacted their alertness. So you had this unfavourable impact that they were consuming more calories if they were dippers, but they also reported less alertness as well.

WERE THERE ANY TRENDS IN THE BIG DIPPERS?

No. We did find that males had slightly larger dips than females. But we found that there was huge variability between individuals just in line with all of our other PREDICT findings. We didn't see that there was a particular trend in terms of age or BMI, etc.

WHAT CAN I DO IF I'M A BIG DIPPER?

There are two factors at play here: one, that some people are more prone to dipping than others, which is down to their unique metabolism and biology. And two, that there'll be some foods that might cause you to have a dip in your glucose, but not cause me to have a dip in mine. And the only way to ascertain that at the moment is to wear a continuous glucose monitor, and to play around and try different foods and see what causes big peaks and dips in your glucose response.

There's also Zoe, the commercial product from the tech company that has been funding this research, which is a personalised nutrition programme. It enables you to monitor your blood glucose, microbiome and other variables that we know are really important in determining how you respond to food

HOW DOES THIS RESEARCH FIT INTO THE IDEA OF PERSONALISED NUTRITION?

We're really starting to understand that we, as individuals, are very complicated, that we have thousands of biological pathways that interact to determine how we respond to food. Likewise, a food has thousands of chemicals, so each and every one of us responds differently. We're starting to understand that a 'one size fits all' approach to guiding people on what to eat doesn't work. We know that dietary-related illnesses are a huge problem worldwide, despite detailed guidance on what we should be eating. But is this because the guidance isn't suitable at that personalised level, or is it that we're not following it?

In healthy-eating guidelines, there's huge scope to personalise what we eat according to what's best for our unique biology. This is really where the field of personalised nutrition is exploding. We're starting to understand this complexity and, more importantly, we're starting to be able to measure it. Until 5 or 10 years ago, we couldn't. But now with the development of these novel, wearable technologies and the possibility of doing remote home-testing, we're in a position where we can start to monitor, at an individual level, how we respond to food.

Measuring just your genetics, just your microbiome or just your glucose response has its limitations. And it's important that we look at the many interrelated factors that determine how we respond to food. This is exactly what the Zoe personal nutrition product is doing. And I think this is what readers really need to be mindful of, if they're interested in finding out about their personal responses to food. They need to be looking at the many different factors that impact how they respond to food. They need to be very cautious when undertaking, for example, a genetic-only test because from our research we know that only plays a small role.

DR SARAH BERRY

Sarah is a reader at King's College London and the lead nutritional scientist on the PREDICT programme. ***Interviewed by*** **BBC Science Focus** ***commissioning editor Jason Goodyer.***

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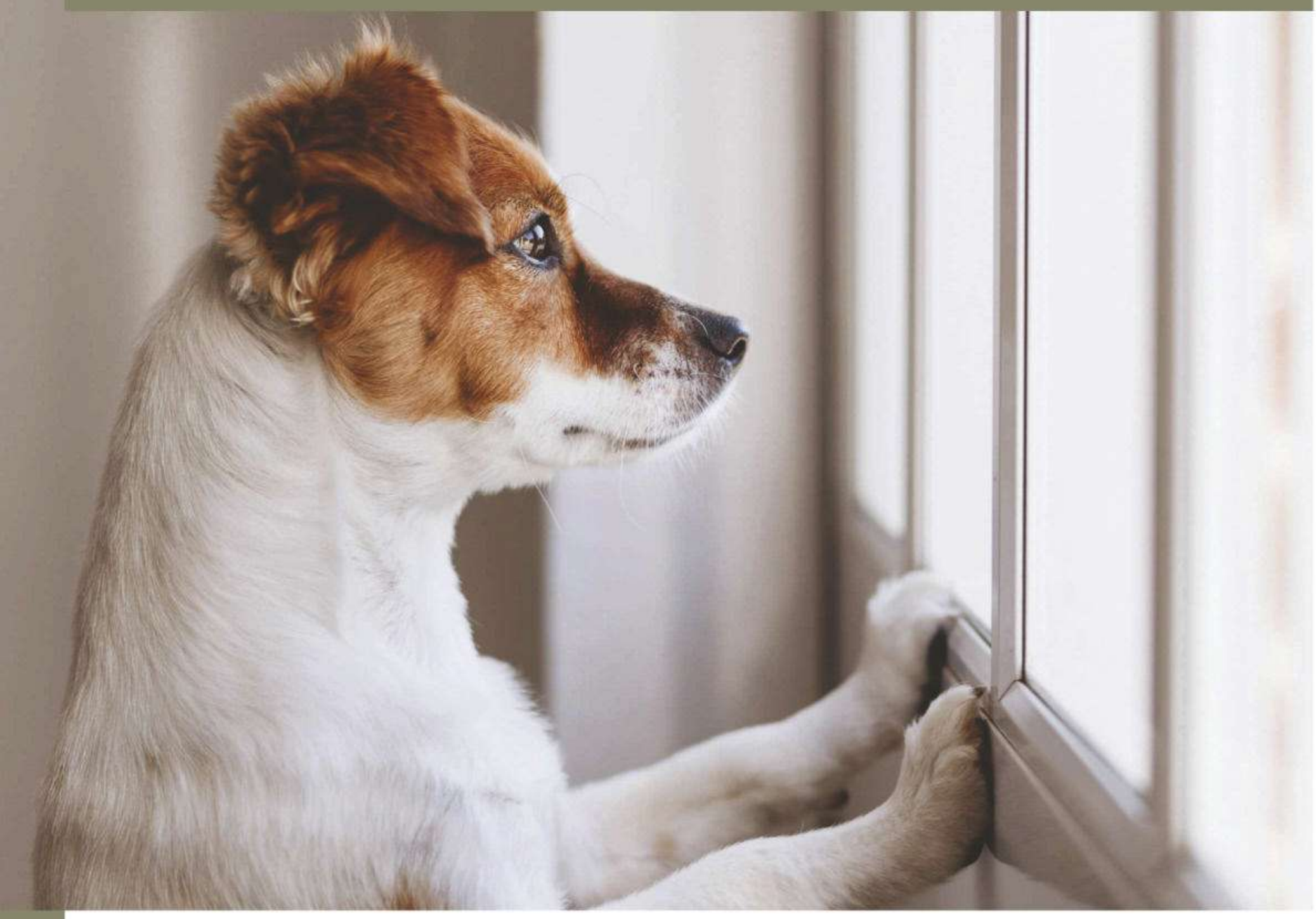
REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Lonely dogs | Stool-gazing | COVID-19's origins



ANALYSIS

COVID-19: WILL MY DOG GET LONELY WHEN I GO BACK TO THE OFFICE AFTER LOCKDOWN?

With lockdown turning us into constant companions for our canines, how are they likely to react when we start leaving them home alone for most of the day?

"Understanding why an end to lockdown may cause problems for our dogs empowers us to find sensible interventions ahead of it"

BBC

Visit the BBC's Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

Dogs love to spend time with their human family. So much so that we usually have to actively teach them as puppies that it's really going to be okay if they're not with us every minute of the day. Now that our dogs have got used to us being around all the time during lockdown, how will they cope when we go back to the office? Will they have unlearned the lessons from puppyhood about being left along and suffer from separation-related distress? What can we do for them to help them adjust to another dramatic change in daily routine?

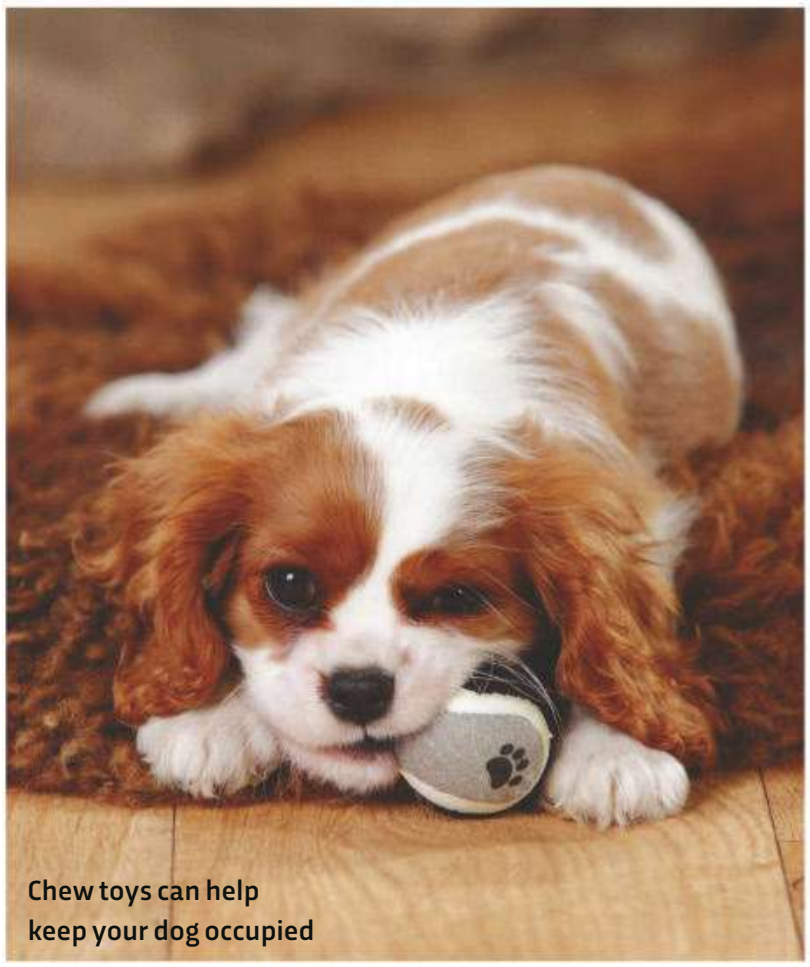
The answer to the first question depends on the individual dog. Some dogs will have been prone to separation-related distress in the past, and for them, a change from nearly always having their humans around to rarely having their humans around is likely to rekindle their distress at being left alone. Another subset of the companion dog population is prone to general anxiety. That may manifest in a variety of ways, such as excessive barking, fearfulness, aggression, self-harm and other less obvious problem behaviours. These dogs may or may not have shown separation-related distress in the past, but any large and sudden change in their daily routine is likely to cause them significant distress. Some of these dogs may have been difficult at the beginning of lockdown, being unusually noisy, destructive, disruptive or needy as a response to suddenly having humans around all the time. Then there are the dogs that were acquired during lockdown, either as a puppy or an adult dog, and have never known life in their current home where they've been left alone for extended periods.

Dogs are keenly aware of contrasts in their environment, so a period when humans are nearly always present in the home will contrast sharply with a period when they're suddenly away for most of the day. That alone can be enough to be disruptive and challenging for them to cope with. So even if you have a well-adjusted dog that was easily taught to accept alone time when you took ownership of them and has never since shown any sign of separation-related distress, they may still struggle with an abrupt change in routine.

Understanding why an end to the lockdown may cause problems for our dogs empowers us to find sensible interventions ahead of it. The most likely cause of trouble is a sudden and dramatic change in living circumstances. Knowing that, we can prime dogs for our return to the office and simultaneously get an idea of how problematic it's going to be for them by starting with short absences and using a webcam or security camera to see how they handle being alone. If they spend more than 20 minutes pacing, vocalising, drooling, panting (assuming it's not hot), or directing destructive behaviours at doors or windows, then you might have a serious problem and should speak to your vet about medication to assist. We don't want our ▶

BELOW Destructive behaviours while you're out might mean your dog requires some more reassurance that you're going to return

GETTY IMAGES X2



Chew toys can help keep your dog occupied

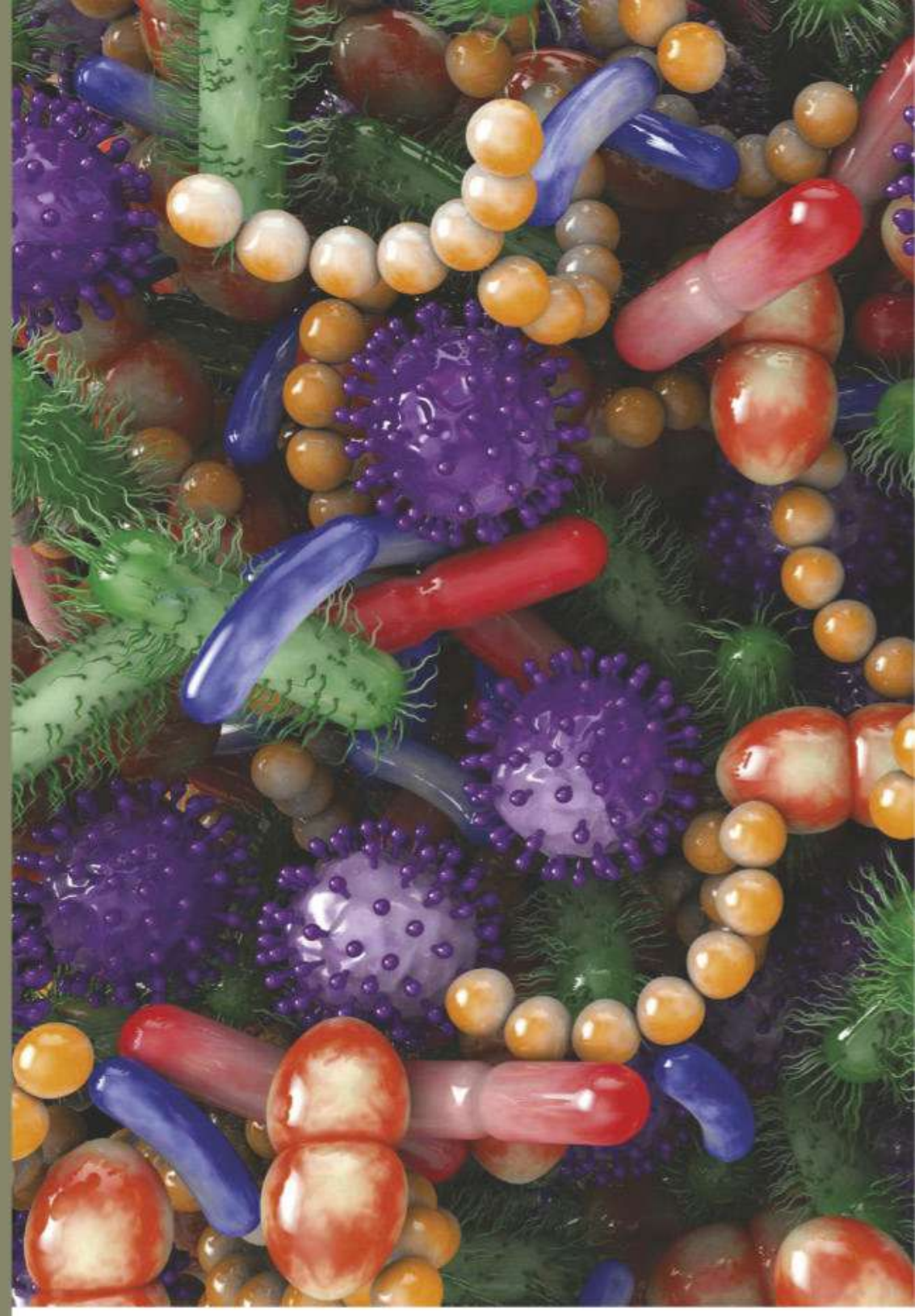
dogs to be miserable if they don't need to be. If they can go and lie down and nap soon after being left, then try a longer absence. Even if all that can be managed is several absences of less than 30 minutes a day, this will still act to ease your dog into post-lockdown life where you won't be around so much.

Another way to ease a dog into human absences is to make sure they're relaxed about being left to amuse themselves while you move around the house. This can be achieved with long-lasting chew items such as boredom-buster toys or a bone. The goal is to see your dog comfortably sticking with their chew item while you get up and leave the room. You may need to start small – just standing up and then sitting down beside them again.

A lot of humans struggle with sudden and dramatic changes as well, so as we move towards what we call 'normalcy', we should appreciate that our own sense of what's normal has changed and we have longer memories than dogs. Many humans appreciate big changes to be incremental in nature and dogs are just the same. We have the opportunity to create increments to help them adjust, even if it takes some creativity. So do your dog a favour and think about how to achieve gradual changes for them.

by **DR MELISSA STARLING**

Melissa is a postdoctoral researcher at the University of Sydney and holds a PhD in dog behaviour.



ANALYSIS

POO: SHOULD WE BE PAYING MORE ATTENTION TO IT?

The trend for stool-gazing has health-conscious people staring into their toilet bowls. Before you don the rubber gloves, let's flush out the truth from the pseudoscience

Stool-gazing may sound like something Gwyneth Paltrow dreamt up, but we've been doing it for centuries. A 1958 article in the *British Medical Journal* explained why. It said that "stools are like the skin, being readily visible, frequently examined, accessible to study and scrutiny, subject to loathsome and malodorous diseases."

GETTY IMAGES, ALAMY

ABOVE The general health of your gut bacteria might be indicated by the ratio of good and bad bugs present in your faeces

The ick factor, plus questions over its reliability as a diagnostic tool, mean it goes in and out of fashion. In the noughties, television presenter Gillian McKeith encouraged people to look at and even prod their poo on the show *You Are What You Eat*. Her qualifications were later questioned and the practice passed out of public consciousness once again. For most of us, gazing into the toilet bowl looking for answers was about as much use as reading tea leaves.

Now, stool-gazing is back, promoted by growing interest (both popular and scientific) in the human microbiome. Gut health is an active area of research, with new papers constantly being published, linking the bacteria that live in our guts to a wide spectrum of health issues, from dementia to depression, and heart disease to chronic inflammatory diseases.

In January, Prof Tim Spector published a paper in *Nature Medicine* that found you can pick out the ratios of good bugs and bad bugs in a person's gut.

"It's basically the first in-depth paper looking at the links between food, gut microbes and health in 1,000 people," he says. "This basically showed that there was a common group of 30 microbes that were associated with good and bad foods, and good and bad health outcomes. The ratio of good to bad bugs was actually the best test of your general health. We can also look at these microbes to see how you might digest fat or how you would deal with a carbohydrate meal."

> "The aim is to build an app that might offer users bespoke advice depending on what pops up in their poops"

This is where modern stool-gazing companies come in. Armed with the ability to conduct shotgun sequencing on a given stool sample, "we can measure every gene and every microbe, and then put it together like a giant jigsaw puzzle," Spector says.

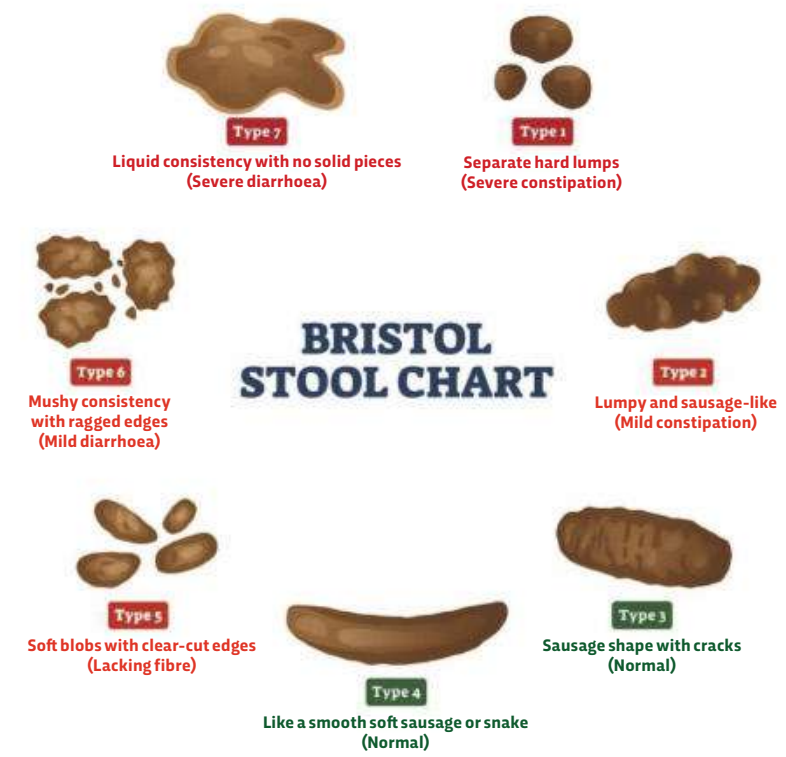
Spector is a founder of one such company, Zoe, which is due to launch in the UK later this year. It analyses your stool samples and offers personalised lifestyle advice based on its findings.

Another example is Seed.com, a probiotics company established by an all-star team of researchers. In 2020, it also invited users to "give a s**t for science" by taking photos of their stools and uploading them to an online database designed to teach artificial intelligence how to categorise the differences in one movement to the next. The aim is to build an app that might offer users bespoke advice depending on what pops up in their poops.

There are also cautionary tales. The founders of a San Francisco start-up called uBiome stand accused of defrauding investors and health insurance companies in the US. Their now-defunct company offered similar services, but with more basic technology.

You don't necessarily have to go to the lengths of genetic tests, however. If you want to get the scoop on your poop, you may wish to consult the Bristol Stool Chart. This (extremely visual) diagnostic tool was designed at the Bristol Royal Infirmary in 1997 as a simple means to evaluate a given stool sample.

It classifies human waste into seven categories from extreme constipation to extreme diarrhoea and ➤



The state of what you leave behind in the bowl can provide clues as to the health of your gut

is used to diagnose irritable bowel syndrome among other things. It also shows you what an 'ideal' stool looks like, although some clinicians believe it's better used by doctors than the general public.

Spector says that one thing worth tracking is how often you go to the toilet or how long it takes after you've eaten something noticeable, such as sweetcorn, to reach the bowl.

"We've just published a paper that we called the Blue Poo study where we got 1,000 people to swallow a muffin coloured with blue food dye. And the transit time – the time it takes the muffin to reach the toilet – is a pretty good indicator of your gut health.

"Obviously you don't want to be going too fast, but people who go to the toilet once or twice a day definitely have healthier guts than people who only go once or twice a week."

Spector also practices what he preaches. "I eat 30 different plants a week, which includes nuts, seeds and herbs, so it's not as hard as it sounds," he says. "I eat fermented foods like yoghurt and kefir every day. I have high-polyphenol foods, such as red wine and dark chocolate, berries, nuts. I do occasional intermittent fasting or time-restricted eating where I skip breakfast once a week. And I limit junk food. If you follow those rules you're half of the way there."

—

by **IAN TAYLOR**

Ian is a freelance writer and was formerly the deputy editor at BBC Science Focus.

COMMENT

COVID-19: WHY IS IT SO DIFFICULT TO FIGURE OUT WHICH ANIMAL IT CAME FROM?

Was it bats? Was it pangolins? Was it both? Was it something else? Finding the origin of SARS-CoV-2 is vital for fighting future epidemics

It has been 16 months since we first discovered the SARS-CoV-2 virus. Over this time there have been many studies trying to figure out where the virus came from and how it first infected humans. There's very good evidence that the virus evolved naturally, that it was spreading in China earlier than December 2019 and that it jumped from an animal host to humans. We still don't know which animal hosts were involved, however, or exactly when this jump into humans occurred.

We know that one of the closest relatives of the SARS-CoV-2 virus, RaTG13, has been found in horseshoe bats in a cave in the Yunnan province of China, nearly 1,000 miles away from Wuhan, where the pandemic began. While the RaTG13 virus is very similar to SARS-CoV-2, it contains differences in the spike protein receptor binding domain (which is the part of the virus that grabs on to the ACE2 protein on a human cell at the start of the infection). The differences suggest that RaTG13 would not infect humans well, meaning that RaTG13 is not likely to be the parent of SARS-CoV-2. Instead, it's thought that the RaTG13 virus, or a similar one, may have jumped from bats to a different intermediate animal host, where the virus further evolved before jumping into the human population.

Early research found additional, related viruses in pangolins in China. While overall these pangolin viruses were not as closely related to SARS-CoV-2 as RaTG13, they showed a similar spike protein receptor binding domain that could likely infect humans. From these results, it was suggested that SARS-CoV-2 may have evolved when a pangolin SARS-CoV-2 and a RaTG13 virus recombined, creating a new virus that could readily infect humans, and that was what started the pandemic. But further research has found no evidence that this recombination actually occurred and instead suggested that SARS-CoV-2 viruses have evolved in horseshoe bats in China over the course of several decades and

GETTY IMAGES, DR LIBIAO ZHANG/GUANGDONG ENTOMOLOGICAL INSTITUTE

“If we’re able to discover the origins of the virus we may learn if there’s an unknown reservoir of it in some wild animal population that may pose risks of future SARS-CoV-2 outbreaks”

didn’t necessarily require an intermediate host for transmission to humans.

To attempt to prove the origins of SARS-CoV-2 in bats or other animals as intermediate hosts, the World Health Organization recently led an exploratory mission to China looking for traces of related viruses in many different types of wild and domesticated animals. Despite thousands of samples, the precursor virus to SARS-CoV-2 was not found. It’s possible that the virus still lurks in untested animal populations near Wuhan. It’s also possible that the virus came from further away, travelling to Wuhan through intermediate hosts or through the wild animal trade. But we may never know. It can take years until the animal reservoir of an infectious disease is identified and for some diseases, the exact origins often remain unknown. Despite these difficulties, the hunt for the origins of SARS-CoV-2 will continue.

There are good reasons to look for the origins of the SARS-CoV-2 virus, although they may not directly affect our current situation or our ability to control the pandemic. If we’re able to discover the origins of the virus we may learn if there’s an unknown reservoir of the virus in some wild animal population that may pose risks of future SARS-CoV-2 outbreaks. This is especially true if we discover that the virus did evolve solely in bats and doesn’t need further evolution in an intermediate host before it’s able to infect humans.

We may also discover related SARS-CoV viruses and be able to take steps to prevent their jump into humans. In the long run, by understanding where the virus came from, we’ll be better positioned to stop new animal viruses entering the human population, possibly preventing future pandemics. **SF**

ABOVE SARS-CoV-2 may have been evolving in Chinese rufous horseshoe bats (*Rhinolophus sinicus*) for decades before becoming a threat to humans

by **DR JEREMY ROSSMAN**

Jeremy is a senior lecturer in virology at the University of Kent.

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INNOVATIONS

PREPARE YOURSELF FOR TOMORROW

As seen in this visualisation, the vessel will include a 'science sphere', jam-packed with state-of-the art technology

FLOOD THE DESERTS

Silicon Valley firm Y Combinator has a radical and untested idea: flood desert basins with water to create algae farms that soak carbon from the atmosphere. They could also potentially create new ecosystems from previously uninhabited land.

BLOCK OUT THE SUN

Geoengineering projects have long been considered as a last-gasp solution to climate change, but Harvard scientists are conducting a feasibility study into stratospheric aerosols that lower global temperatures by reflecting solar energy back into space.

SHOOT FOR THE MOON

Scientists from the University of Arizona want to create a biological insurance policy for life on Earth. An 'ark' with sperm, ova, seeds and spores from 6.7 million species would be sent to the Moon and stored in a solar-powered repository.

CLIMATE CHANGE

The atomic superyacht on a voyage to save the planet

You can join 160 scientists on board for a cool £2.2m

This is a nuclear-powered research vessel that's the size of a cruise ship and packed with 22 laboratories. It's being built by an entrepreneur with a shade of Tony Stark about him. When it launches in 2025, the ship will carry 450 people, including scientists, environmentalists and the odd billionaire, on voyages to study the climate.

The *Earth 300* is ambitious but that's the point, according to the man behind it. Aaron Olivera wants to build an awe-inspiring object that will galvanise interest in climate change. He describes it as this generation's Eiffel Tower, or the Olympic Torch of global science.

"It has been designed to capture people's attention but also their hearts and imaginations," Olivera says. "If we want to make big, bold changes we need everybody's help, all ages, backgrounds and even all types of intelligences."

"THE SHIP WILL HOUSE THE WORLD'S FIRST COMMERCIAL, OCEANGOING QUANTUM COMPUTER"

The vessel will be almost 300m long and feature a 13-storey 'science sphere'. Olivera wants to bring together an Avengers-style team of scientists working in a range of disciplines to collaborate on new climate solutions, with state-of-the-art technology to help them.

With built-in sensors, artificial intelligence, robotics, machine learning and real-time data processing, the ship will also house the world's first commercial, oceangoing quantum computer to handle the vast amounts of data it collects. *Earth 300* will be open-source, its data shared with other climate scientists.

It will be zero-emissions, powered by atomic energy from an onboard molten-salt reactor. Described as an atomic battery pack, it's based on technology created by TerraPower, a nuclear innovations company set up by Bill Gates.

"At present, both quantum computing and a molten salt reactor have never been installed on a ship," Olivera says. "Both will need an extreme level of engineering to get to that stage."

None of this comes cheap. *Earth 300* executives believe the ship will cost between £350m and £500m to build. Private investment and a number of partnerships are helping to fund it, but VIP tickets will also be sold to wealthy tourists. For £2.2m, you can buy a 10-day cruise on the ship, staying in plush quarters with front-row seats to game-changing science.

Olivera and his team believe that radical thinking is needed to invigorate new research and interest in climate change, and the survival of life on Earth. While Elon Musk and Jeff Bezos aim for the Moon, Mars and beyond, Olivera is focusing his efforts here. "We are living at a pivotal moment in human history and facing the greatest challenge to our civilisation since the dawn of humankind," he says. "But we also live at a time where we have access to the talent, tools and technology to address any significant challenge. We saw no reason to not think big, we wanted to wake up the world and bring a new awareness that allows us to see ourselves as biospherians where we can come together and solve any problem."

The *Earth 300* research vessel will be powered by atomic energy

UPGRADE YOUR GARDEN

Those post-lockdown garden parties are coming – here's our pick of the best kit to spruce up your green space this summer

1 Innr Outdoor Smart Lighting

Pedestal three-light starter kit, £149.99, innr.com

Innr's range of outdoor smart lighting should help keep the party going past sunset. Choose from pedestal lights, spotlights and lighting strips for a setup that works for your space, then control them all using the Innr app on your phone. The app allows you to choose when they come on, programme an automated schedule, build your lighting into a smart home routine and choose what colour you want the lights to be. You can even adjust them using your voice with Alexa or Google Assistant.

They work on the Zigbee protocol, so you'll need a control hub that supports this. Some of Amazon's more recent Echo family already have Zigbee support built in, but otherwise installing the Philips Hue Bridge or Samsung SmartThings Hub will do the trick.

Innr's lights come in sets of three, but can be expanded to as many as 10 lights using one control box, or use several control boxes if you'd like to control lights separately. They're easy to install, but will require an outside plug, so that's the only bit you'll need an electrician for.

2 Nebula Mars II Pro

£549.99, uk.seenebula.com

For summer movies al fresco, why not invest in a portable projector like the Anker Nebula Mars II?

The Mars II has everything you need in a single box, making it simple to get started. It has built-in Wi-Fi for access to Netflix, Amazon Prime Video and BBC iPlayer, a decent speaker, and a rechargeable battery that'll give it four hours of runtime away from a plug. It's easy to set up, with automatic focusing and keystone correction, so all you need to do is point it at a blank wall and let the projector do the rest. It's capable of projecting a picture of up to 254cm with a resolution of 720p HD, though we'd recommend keeping it smaller for the best picture. We'd suggest waiting until it's as dark as possible to kick off the movie, as the light output of 300 lumens isn't the brightest. Still, with ease-of-use on its side, it's perfect for adding a bit of fun to those balmy nights.

3 Weber Connect

£155, weber.com

Summer means barbecues, and if you're in charge of the cooking, you'll know the pressure of getting the meat cooked just right.

Barbecue kings Weber have thankfully come up with a clever bit of tech that means you can get it spot-on every time, and also give you a bit of freedom away from standing next to the grill.

The Weber Connect acts as a step-by-step barbecuing assistant, keeping you in the know when the burgers need flipping and sausages need turning.

It comes with two probes for placing into the joints you're cooking, but can host an additional two probes to keep an eye on four different pieces of meat at any one time. These will monitor the temperature of the meat and, with the accompanying app, will walk you through the steps to getting it right every time, including different guidelines depending on how you want it cooked.

It works over Wi-Fi and Bluetooth and can work with your current barbecue, so there's no need for an overly expensive overhaul to tech-up your grilling.

4 Cooper Cooler drink cooler

£185, coopercooler.com

Ice-cold drinks are a must on a warm day, but when the fridge is full of food for the barbie and you've got thirsty guests, you might find yourself hard pushed to get the drinks cool (and no one likes a warm glass of Prosecco).

Whether it's a can of cola, a beer or a bottle of wine, the Cooper Cooler will take your warm beverage and make it ice-cold in a matter of minutes. All you need to do is load it up with ice and water, choose the drink you want to chill and set it going. The Cooper Cooler rotates your drink (gently – there'll be no explosions once you remove it from the cooler) and sprays it with ice-cold water to get it to the same low temperature throughout. The result is a fridge-cool beer in a minute, or a bottle of wine in around six minutes. Absolute game changer.

5 Ooni Koda 12 pizza oven

£299.99, uk.ooni.com

Barbecues might be the king of the summertime feast, but eating proper stone-baked pizza al fresco? Count us in!

The Ooni Koda 12 is a gas-powered pizza oven that's ready to go straight out of the box, and less faff than messing around with wood or charcoal. Just hook it up to the gas, pop in the stone baking board and you'll be ready to cook within 15 minutes.

Reaching temperatures of up to 500°C, it'll cook your home-crafted pizzas in just 60 seconds so there's no dilly dallying either.

Of course you don't have to stop there – you can use the Ooni Koda 12 for roasting fish or veg, and cooking steaks. The adjustable dial allows you to set it to temperatures that will work for the food at hand.

Once you've finished cooking, pop the board out for cleaning, fold away the legs and the oven is nice and compact for storing in a shed, or even in your kitchen.

6 Kitsound Diggit 55

£39, kitsound.co.uk

If you're looking for an affordable Bluetooth speaker to set the soundtrack to your parties, the Kitsound Diggit 55 is made for the great outdoors – quite literally.

It comes with a removable stake for sticking it into the ground, 360° sound from dual opposing drivers for spreading your music in all directions, and an Outdoor EQ Mode that gives the volume and bass a little boost to better suit an outside environment.

Want a more expansive sound? Buy two speakers and you can create a stereo pair for a more immersive soundscape.

The Kitsound Diggit 55 has tough IP55 resistance to dust and water, a 15-hour battery life and an LED downlight for adding a bit of a glow to your night-time garden party. Its wooden design looks the part too, so it is stylish enough to be taken inside when you retire for the evening.

7 Sonos Move

£399, sonos.com

Sonos has been one of the best multi-room systems you can buy for your home for some time. However, as its speakers have always been reliant on Wi-Fi and mains power, the garden has been left out. That is, until recently. The Sonos Move can be used anywhere, thanks to having Wi-Fi and Bluetooth built in.

Within your home's Wi-Fi, it can be used as part of your multi-room system; away from home, you can use it with Bluetooth and stream from your phone.

It offers 10 hours of wire-free playback, is weatherproof and has a carry handle. When it's time to charge, just pop it back on its charging ring and it'll be fully juiced up in three hours.

As you'd expect from Sonos, it sounds fantastic, helped along by the Move's Auto Trueplay functionality. This learns a little about the environment it's playing in and adjusts the sound to ensure it's making the best of your music.

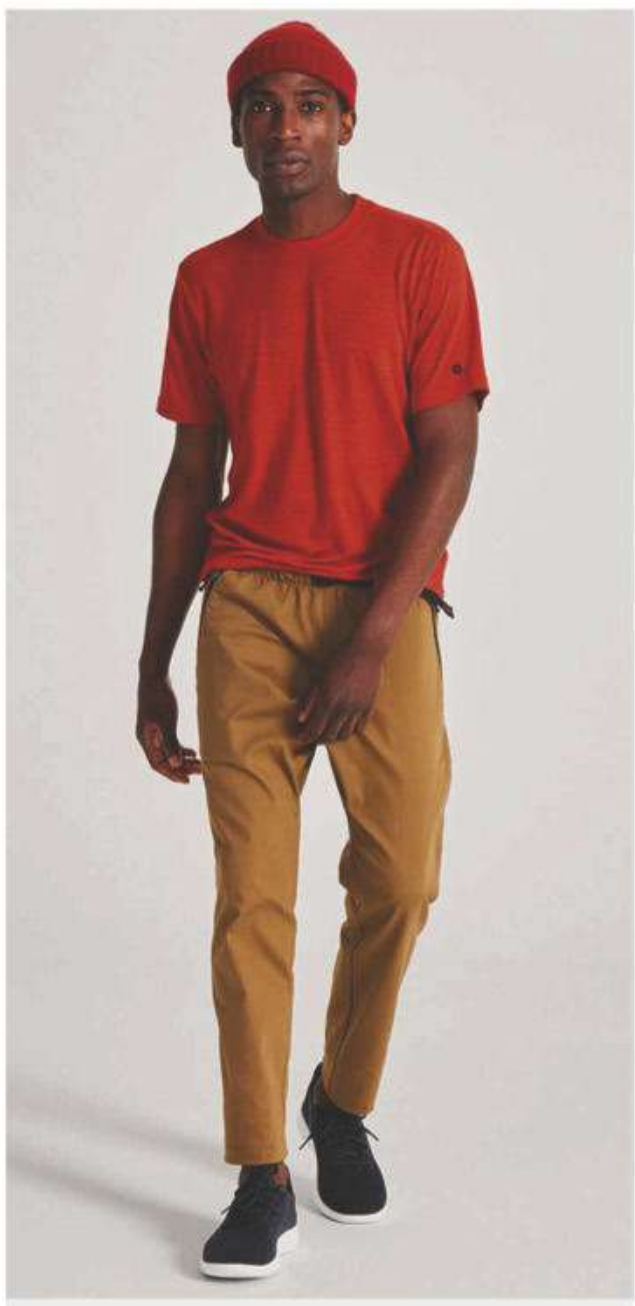
Ideas we like...

→

...an easy-to-use drone racer

Fancy yourself as a drone pilot? DJI's new drone beams the view from its camera straight to a headset back on terra firma. You see what the drone sees. It's a user-friendly version of what drone-racing pilots use in competitions. The drone itself can move at a max speed of 140km/h (87mph) and can reach 0-60mph in just two seconds. It has a max range of 10km (6 miles), but you'll need a spotter who can keep an eye out for people or obstructions below while you fly. The tech is pretty power hungry, so you'll get a maximum of 25 minutes out of a flight, but it will be one helluva ride.

DJI FPV
£1,249, dji.com



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...an odour-fighting T-shirt made of recycled crab

Yes, you read that right. This unassuming T-shirt is made of chitosan, a material obtained from the exoskeletons of shellfish. It's one of the most abundant ingredients on the planet, so its creators, Allbirds, decided to use it to make some of its clothing line. According to Allbirds, this special blend also has odour-fighting properties (it presumably has a surface that's hard for smelly bacteria to colonise), which hopefully means you have to wash it less, and it'll last longer.

TrinoXO Tee
£45, allbirds.co.uk

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...a breathable memory foam/spring hybrid mattress

As you can tell from our cover feature (p52), a good night's sleep is one of the most important things you can do for your health and wellbeing. Memory foam mattresses are fashionable, but their spongy embrace isn't for everyone. Simba's patented hybrid solution pairs springs and memory foam to create a mattress that's firm, ensures two people sleeping in a bed won't feel each other move around, and is cooler than memory foam. The company's latest upgrade, the Hybrid Luxe, adds a second set of springs to provide extra support and remove any chance of sore joints for side sleepers. Plus, Simba has added a breathable bamboo wool layer just beneath the top layer, to help regulate your temperature and fend off a sweaty night's sleep.

Simba Hybrid Luxe Mattress
From £1,099 (single mattress), simbasleep.com

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...a beautiful smart speaker

This might just be the best-looking smart speaker money can buy. Beneath the bookish disguise, the Beosound Emerge is equipped with Google Assistant so it can control any compatible connected home tech. The audio is powered by a separate tweeter, mid-range driver and subwoofer so it will create room-filling, detailed sound, despite its size. And if you somehow have enough spare cash to buy two, you can pair it with a second speaker to create stereo sound.

Beosound Emerge
£669, bang-olufsen.com

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...next-gen VR

Details are thin on the ground about virtual reality on next-gen consoles, but Sony has revealed what its motion controllers (which will translate your hand movements into the virtual world) will look like. Of particular interest is the finger-touch detection that senses where your digits are placed on the remote. This will enable you to pick up and manipulate objects in the virtual world in natural way.

PS5 VR controller
£TBC, blog.playstation.com

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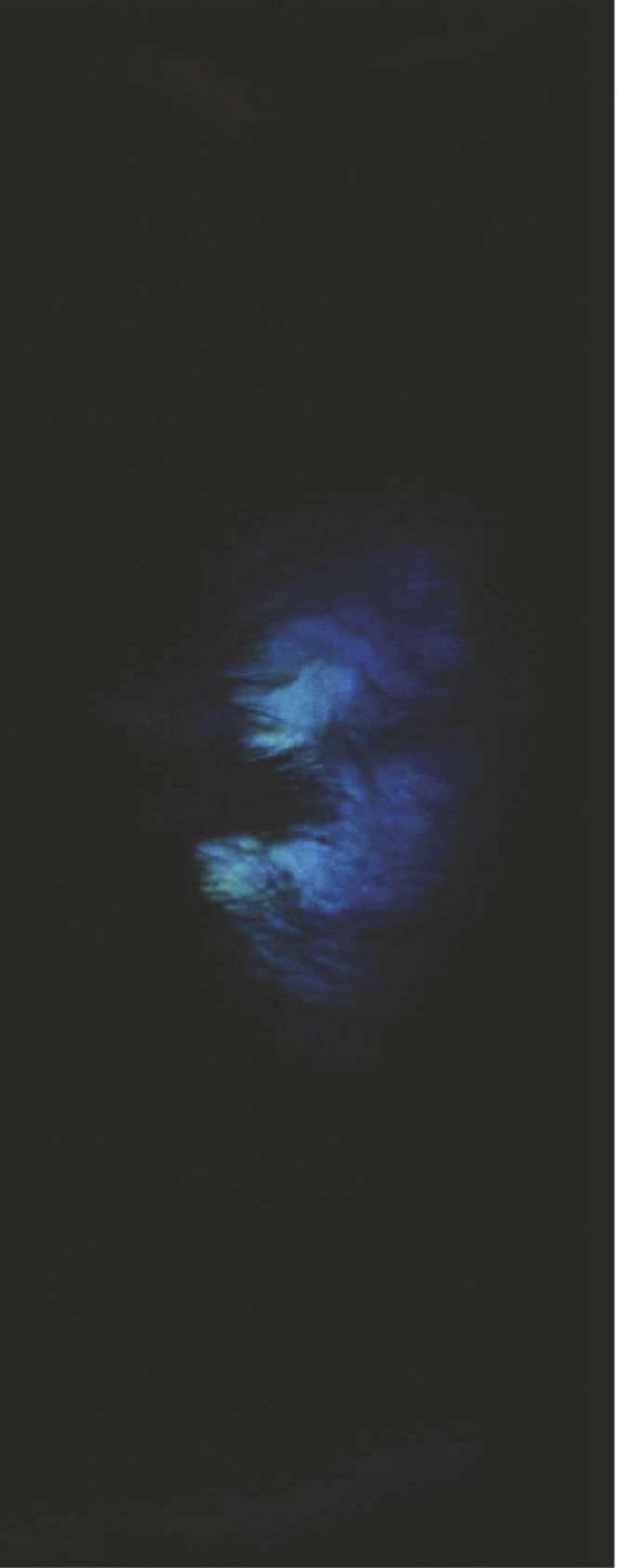
...air purifiers

While many of us know air pollution harms our health, we may have overlooked what's happening inside our homes. It turns out that cooking and cleaning are filling our homes with pollutants at higher concentrations than those outside. Even our furniture is off-gassing formaldehyde – a chemical used in its production. So what can you do? Well, you could just reject society and retreat to the woods (we've considered it a few times this year), but if that's not an option, you may want to consider an air purifier. The latest version of Dyson's Purifier Hot+Cool is kitted out with filters to tackle the particles invading our home's air, including formaldehyde. It also has loads of sensors to provide insight into what's generating the most pollution (cooking, in our case, made the air quality 'severe'), and it doubles as an effective fan or heater.

Dyson Purifier Hot+Cool Formaldehyde
£599.99, dyson.com



JAKE SCHOEN/TOLEDO ZOO

TIME TO SHINE

A FEW YEARS AGO, SCIENTISTS BELIEVED ONLY A TINY BAND OF CREATURES COULD EMIT LIGHT. BUT A STRING OF NEW DISCOVERIES HAS ILLUMINATED A WIDER WORLD OF GLOW-IN-THE-DARK LIFE FORMS

WORDS: JULES HOWARD

DEVIL MAKES LIGHT WORK

"It was pretty shocking when we saw it," Jacob Schoen, a technician at an Ohio zoo told local reporters in December 2020, just before the global media circus descended. The source of this storm? This image, clearly showing that the Tasmanian devils housed in their enclosure were fluorescing after-hours – parts of their faces were, quite literally, glowing in the dark. Certain Australian mammals, including Tasmanian devils, are thought to manage this via arrangements of special proteins in the skin and fur that absorb energy from sunlight during the day. At dusk, they re-emit this energy in a different wavelength – one invisible to humans without the use of blacklights or ultraviolet (UV) torches, which translate these hidden wavelengths into colours our eyes can process. The big question zoologists are now asking is: why? What role does fluorescence play in animal communication? Week-by-week, month-by-month, other animal discoveries are lighting a path towards answers.

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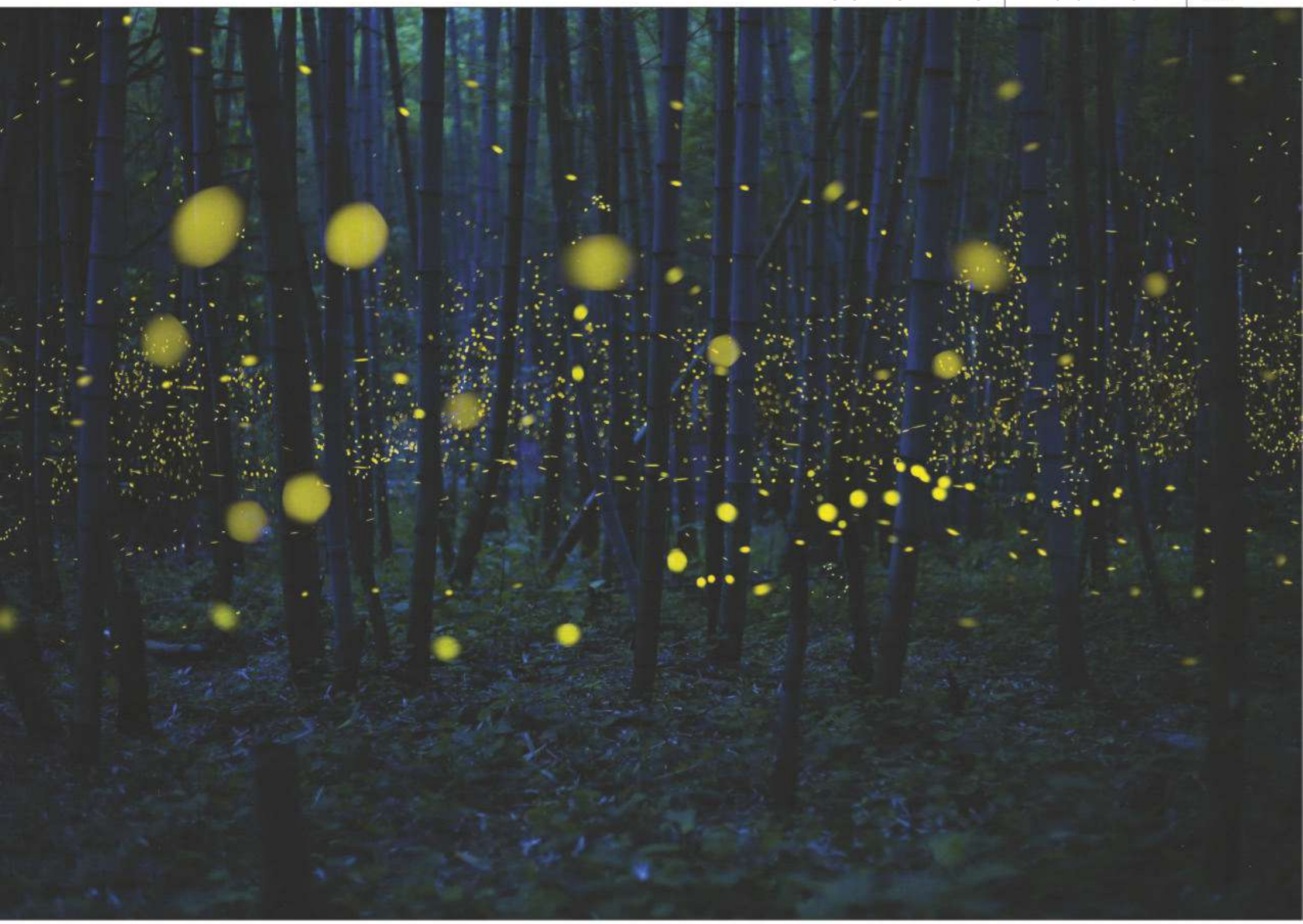
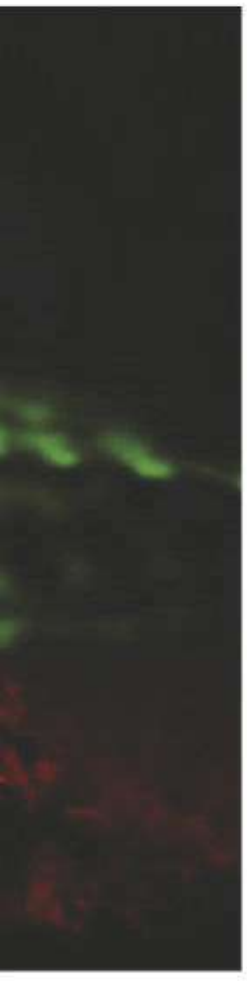
STRIKE ME PINK

In February this year, an African rodent called the springhare became one of the first non-Australian mammals known to fluoresce. A secret patchwork of luminous markings was discovered upon its flanks, each made up of organic compounds called porphyrins found in the fur. Each individual (male or female) appeared to have its own unique patterns. This differs from marsupials such as echidnas, where fluorescence tends to occur in distinct regions of the body, such as the eyes, ears or nose. Quite what purpose these blobs serve has become a hot topic among scientists. Some argue it may be a meaningless side effect as porphyrins break down at different speeds across the fur. Others argue that the patterns may help individual springhares recognise one another, or that the phenomenon is some form of cryptic camouflage – visual 'noise' to deter predators.





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LUMINARY LIFELINES

This lizardfish, previously unremarkable, lights up like a toothy space-dragon when illuminated with a special torch. It is one of thousands of so-called 'cryptic' fish – species that are so hard to spot that few scientists encounter or know much about them.

The lizardfish's photographer Dr Maarten de Brauwer wants to change that. With a powerful blue torch in one hand and a diving mask fitted with a yellow filter, de Brauwer is trialling new ways to make easy-to-overlook fish like these light up like fireworks, in order to help conservation scientists seeking threatened species.

"The biofluorescence survey is exciting and I know more people are testing it out on a wider range of species and environments," de Brauwer says.

Technology like this offers a glimpse of how scientists could use the principles of biofluorescence to understand and protect animals in the future.

J MARTIN/E OLSON/NORTHLAND COLLEGE/OLSON ET AL/SCIENTIFIC REPORTS, GETTY IMAGES, MAARTEN DE BRAUWER

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WHEN SPARKS FLY

The firefly's magnificent light show (captured here in Shikoku Island, Japan) is produced by a chemical reaction that occurs in the creature's abdomen. A molecule called luciferin mixes with calcium and oxygen in the presence of an enzyme named luciferase, causing energy to be released in the form of light. Some of the 2,000 or so firefly species (technically all beetles) pulse their glow. Some flash while looping through the air. Others coordinate their flashes with fireflies nearby.

The firefly's ethereal glow once shone upon the faces of dinosaurs, yet as each decade passes in the modern age, their populations decline. The culprit? Streetlights, which some fireflies confuse for members of their own species during mating season.

"It's one more threat on top of habitat destruction, the climate crisis and use of toxic pesticides," says The Wildlife Trust's Brian Eversham.

←

TUNNEL VISION

In a deep, dark passage, down a deep, dark cave, blue-green stars shine bright. These constellations are made by the larvae of a tiny gnat (*Arachnocampa luminosa*) which produces a nest of sticky threads and then proceeds to glow, attracting flies which it catches and eats. This New Zealand-based fungus gnat is one of a handful of flies known to produce light. Like fireflies, its bioluminescence depends on luciferins, yet a few crucial ingredients, identified in 2018, differ. It appears that by utilising different amino acids such as tyrosine, *Arachnocampa luminosa* has hit upon an independent means to generate light not used by any other animal on the planet.

"The fact that this bioluminescence is derived from a completely different chemical to other bioluminescent species just hints at how much the insects still have to reveal to us," says Dr Erica McAlister, the Natural History Museum's resident fly expert.

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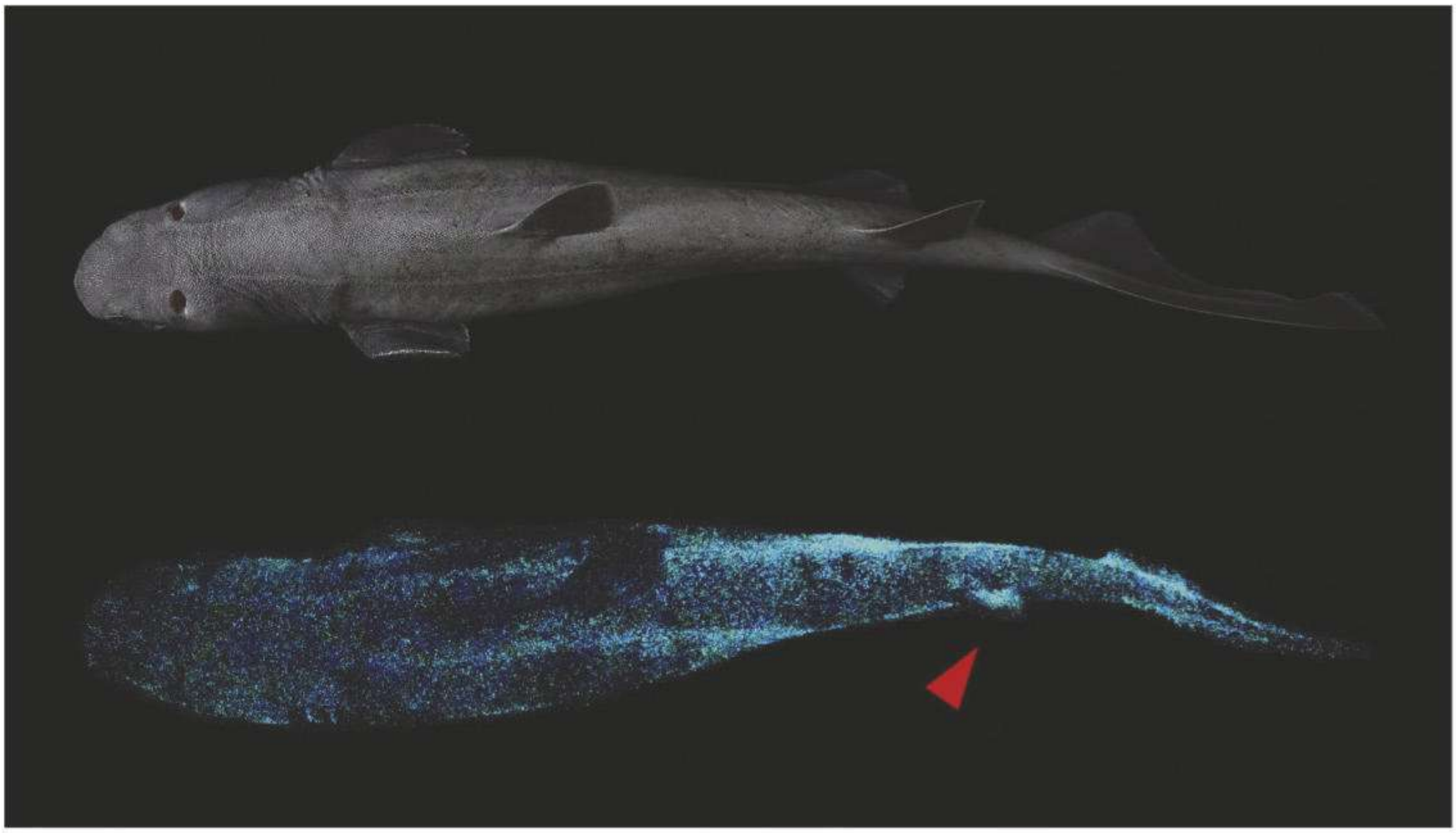
FISHING LIGHT

In the deep sea, where light from the Sun cannot reach, 90 per cent of ocean organisms are bioluminescent – they produce light through the mixing of reactive chemical agents or through light-producing bacteria. Among the most famous bioluminescent animals are the anglerfish, who cultivate special light-producing bacteria called *Photobacterium* in a pouch on their dorsal fin. The ghostly glow that these bacteria produce attracts the attention of small fish, who unwittingly stray into the range of the anglerfish's giant maw.

One of the great mysteries of the deep is where anglerfish get their light-producing bacteria from. Young anglerfish appear not to carry them; neither do males (who are so tiny and inconsequential, scientists overlooked them for years). It may be that anglerfish collect *Photobacterium* from the water, offering the bacteria food and shelter in return for luminary services.



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GLOW IN THE SHARK

"This isn't a small shark trying to blend in with the dim, inky light of the twilight zone to avoid getting eaten, but a big predator that maybe even illuminates the seabed to hunt down prey," says Dr Helen Scales, marine biologist and author of *The Brilliant Abyss*. She is referring to the discovery in March 2021 that a species of shark called the kitefin is able to glow. At 180cm long, it is the largest bioluminescent vertebrate that has ever been discovered.

Many species of deep-water sharks have bioluminescent undersides which, when viewed from deeper in the water by predators, makes the silhouette of the shark disappear against the backdrop of well-lit waters above. The kitefin also has a bioluminescent underside, but far more surprising is its bioluminescent dorsal (upper) fin – an adaptation whose purpose currently remains the subject of intense debate.

The ocean's so-called 'twilight zone' is located between 200m and 1,000m deep, and is both the biggest and least explored habitat on Earth.

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GLIDING LIGHT

Of all the animals that visit birdfeeders, a gliding mammal that glows electro-pink would be a rare treat. Yet that is exactly what Wisconsin-based biologist John Martin saw one night when he shone his UV torch towards an unknown noise. Staring right back at him, with its mouth full of birdseed, was a fluorescing flying squirrel.

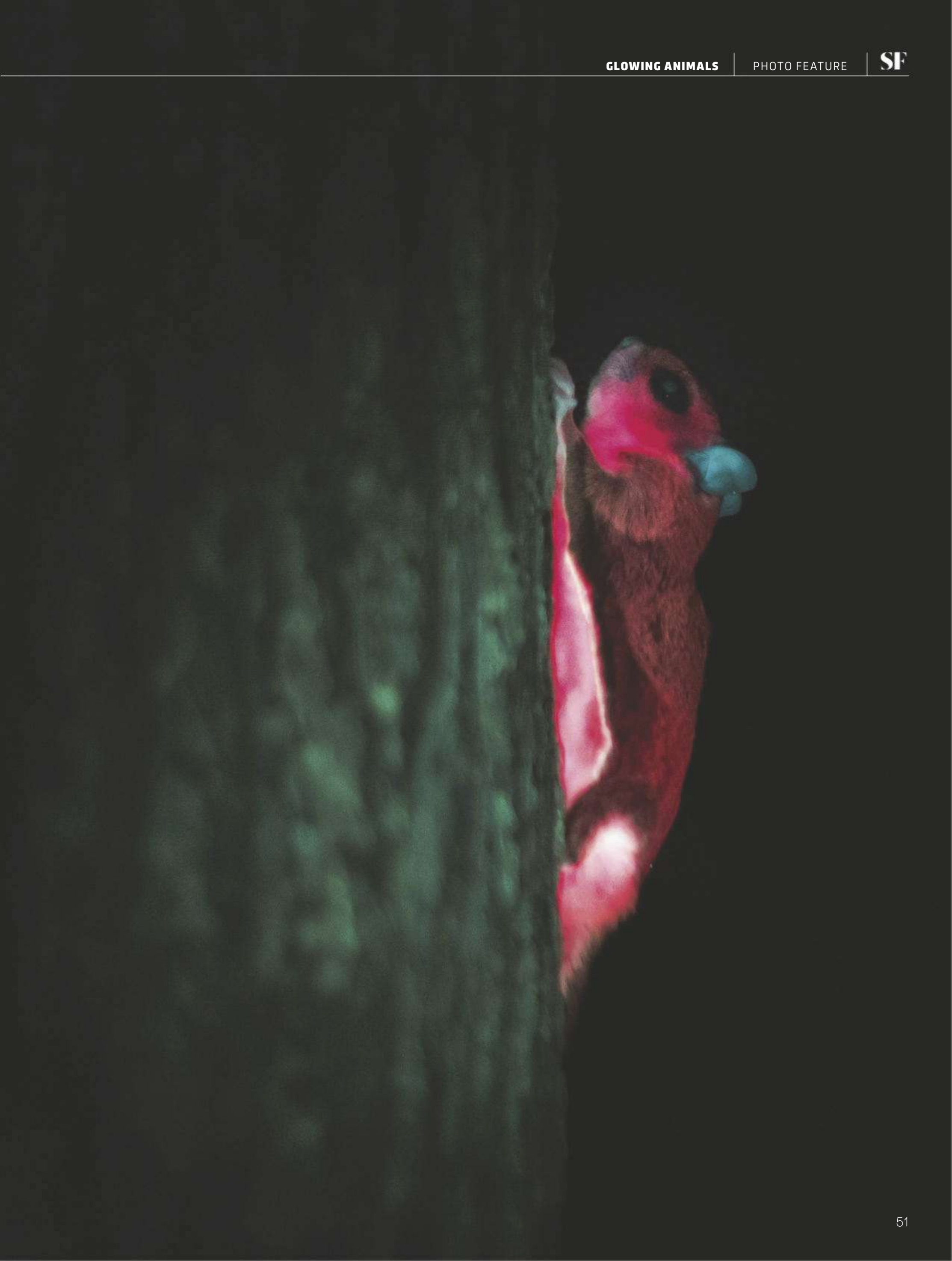
Curious about whether this was a quirk of all flying squirrels, Martin and his colleagues searched for more mammals nearby and asked museum curators to check their stuffed collections using UV flashlights. To their amazement, each of the nocturnal species had the same psychedelic patterns upon the flaps they use to glide. The species active during the daytime did not.

"So far, the link between biofluorescence and a nocturnal lifestyle has held as new observations come in," says biologist Prof Paula Anich, who worked on the study with Martin. "Beyond that, we're not really sure. Camouflage? Or a by-product of metabolic processes that coincidentally fluoresces?" **SF**

by **JULES HOWARD**

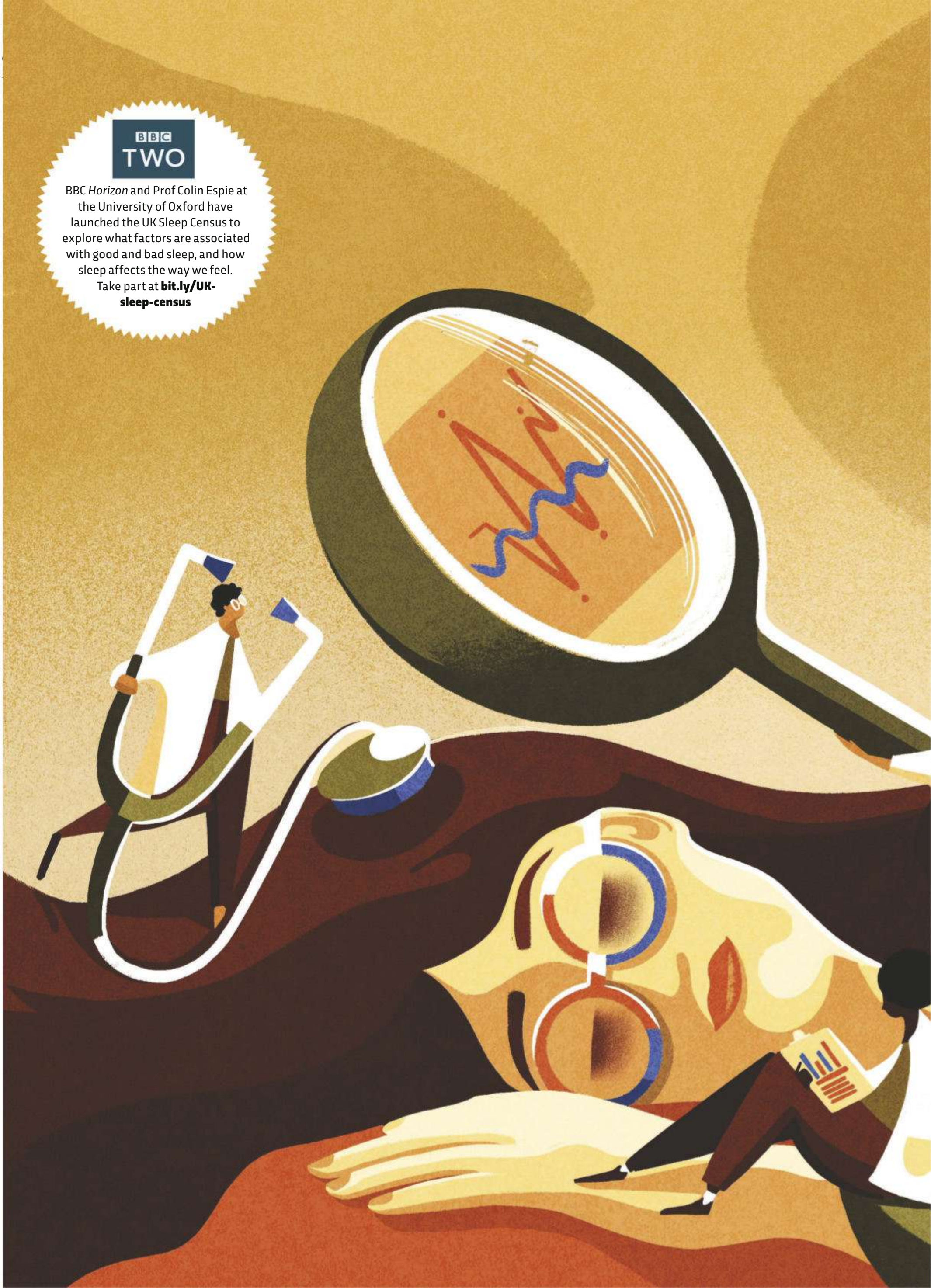
Jules is a zoological and environmental journalist. His latest book is Encyclopedia Of Insects *(£15, Wide Eyed Editions).*

JEROME MALLEFET, J MARTIN/E OLSON/NORTHLAND COLLEGE



BBC TWO

BBC *Horizon* and Prof Colin Espie at the University of Oxford have launched the UK Sleep Census to explore what factors are associated with good and bad sleep, and how sleep affects the way we feel. Take part at **bit.ly/UK-sleep-census**



THE AWESOME POWER OF SLEEP

WORDS: DR MATTHEW WALKER ILLUSTRATIONS: SOPHIE STANDING

by DR MATTHEW WALKER
(@sleepdiplomat)
Matthew is a professor of neuroscience and psychology and the director of the Center for Human Sleep Science at the University of California, Berkeley. He is also the author of the international bestseller, Why We Sleep: The New Science Of Sleep And Dreams, *published by (£10.99, Penguin Random House).*

Our 24/7 society seems to be slowly robbing us of our slumber, but at what cost?

Sleep is the single most effective thing we do each day to reset the health of our brain and body. It's an extraordinary elixir that can help you age well and live longer. Here's what we know about Mother Nature's cure-all...

WHAT HAPPENS IF YOU HAVE TOO LITTLE SLEEP?

Short sleep is associated with an increased chance of having high blood pressure, a heart attack, and/or a stroke. Even the loss of a single hour of sleep can be heartbreaking, quite literally. There is a global experiment conducted on over 1.5 billion people across 70 countries twice a year. You know of this experiment. It is called Daylight Saving Time. According to a study published in 2014 in the journal *Open Heart* that looked at more than 42,000 hospital admissions for heart attacks, in the spring, when we lose an hour of sleep, there is a 24 per cent increase in heart attacks the next day.

Even your hormones take a turn for the worse when sleep is lost. Young healthy men sleeping just four hours a night for four nights end up with a level of testosterone equivalent to that of someone 10 years older, according to a small study published in the journal *JAMA* in 2011. In other words, inadequate sleep, even for a few nights, will 'age' a man by over a decade in terms of such hormonal virility. We see equivalent impairments in female reproductive health and hormonal profiles due to a lack of sleep.

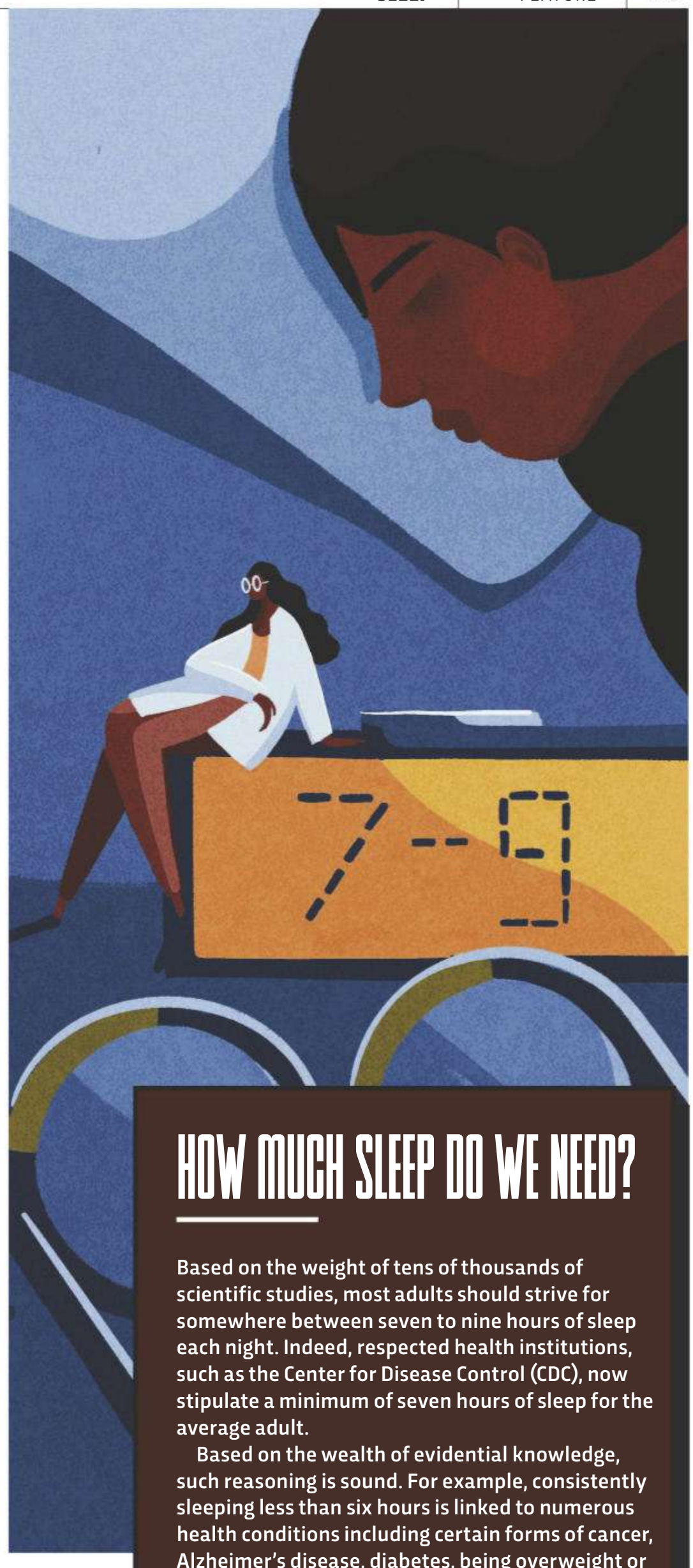
There's also an intimate relationship between your sleep health and your immune health. People who are getting less than seven hours of sleep a night are nearly three times more likely to become infected by a rhinovirus, or common cold. If you are not getting sufficient sleep in the week before getting your annual flu shot, you may produce less than 50 per cent of the required antibody response, rendering the vaccination far less effective. We and others are actively studying whether similar relationships hold for COVID-19.

A lack of sleep significantly increases anxiety, and is associated with higher rates of depression. Recently, studies have shown that insufficient sleep markedly increases the chance of suicidal thoughts, suicide planning, and tragically, suicide completion.

In contrast, proper sleep will gift quite remarkable health benefits in myriad ways, nurturing our memory and learning, and boosting our immunity, physical fitness and mental health.

Strangely, one upside of the pandemic situation that many (though not all) people have experienced is greater freedom with their sleep schedule. When we had to commute and get kids to school, we were forced onto an early schedule. For the larks among us – what we call 'morning chronotypes' – that was fine. But for the

night owls, or 'evening chronotypes', this was brutal. And it is not your choice which of these you are. It is largely genetic. It is not your fault, and it is imprinted during conception. With greater bedtime freedom, we essentially saw a 'revenge of the night owls', as they started to sleep in harmony with their natural, 24-hour biological rhythm. I only hope this freedom remains as we begin to make our way out of the pandemic.



HOW MUCH SLEEP DO WE NEED?

Based on the weight of tens of thousands of scientific studies, most adults should strive for somewhere between seven to nine hours of sleep each night. Indeed, respected health institutions, such as the Center for Disease Control (CDC), now stipulate a minimum of seven hours of sleep for the average adult.

Based on the wealth of evidential knowledge, such reasoning is sound. For example, consistently sleeping less than six hours is linked to numerous health conditions including certain forms of cancer, Alzheimer's disease, diabetes, being overweight or suffering from obesity.

CAN SLEEP KEEP YOUR BRAIN HEALTHY?

Insufficient sleep is fast becoming one of the most significant lifestyle factors that may influence whether you go on to develop the form of dementia we call Alzheimer's disease. It is an area of research my team and I have been fortunate to do a lot of work in. For some years, we knew that people sleeping six hours or less each night, as well as those with sleep disorders such as insomnia and sleep apnoea, had a significantly higher likelihood of developing Alzheimer's disease.

In patients we see with Alzheimer's disease, there is a sticky, toxic protein that has accumulated within their brains, called beta-amyloid. Alongside another toxic protein, called tau, it is a key component of the Alzheimer's disease cascade. Now we know that a lack of sleep is a causal factor resulting in a greater accumulation of beta-amyloid in the brain, setting up a pathway to Alzheimer's disease. Yet the breakthrough came when Prof Maiken Nedergaard, a neurologist at the University of Rochester in New York, revealed a stunning revelation in mice. She discovered a 'sewage system' in the brain that we never knew existed, called the glymphatic system (much like the lymphatic system in your body).

The brain's glymphatic system helps remove all of the dangerous metabolic contaminants and detritus that build up in the brain as we are awake, including and critically, beta-amyloid. However, this cleansing system only kicked into high-flow gear when the mice were in deep sleep. And if you prevent a mouse from getting that essential deep sleep, there was an immediate increase in beta-amyloid deposits in the brain.

Research at my own sleep centre, and studies by other scientists, have shown that a similar vicious cycle exists in humans. Deprive someone of sleep for a night, or even just decrease the amount of deep sleep they get in the first few hours of the night, and we see an immediate increase in the buildup of beta-amyloid the next day, measured in their bloodstream, in their cerebrospinal fluid, and also directly within the brain.

To add insult to injury, we recently discovered that the toxic beta-amyloid unfortunately builds up in the very regions that generate deep sleep, attacking and degrading them. The consequent loss of deep sleep only exaggerates your brain's inability to remove the beta-amyloid at night. Less deep sleep, greater amyloid, less deep sleep, more amyloid.

In this regard, I am always concerned about those individuals in early and mid-life who tell me that they do just fine on four or five hours of sleep a night, since this vicious cycle can take years to play out. Unscientifically, I have always wondered about Margaret Thatcher and Ronald Reagan, both of whom were quite insistent about the uselessness of sleep, claiming only to sleep between four to five hours a night. Sadly, and one wonders if coincidentally, both went on to develop Alzheimer's disease. The ex-US president Donald Trump, also a vocal trumpeter of not "needing" to sleep much, may want to take note.

Prioritising your sleep in early and mid-life may help reduce the risk of Alzheimer's, or at least slow its approach, in later life. Even if you've been neglecting sleep until now, it's never too late to start. Clinical studies have shown that successfully treating middle-aged and older adults' sleep disorders delayed their onset of dementia by up to 10 years.

Without putting too strong a point on it, consider wakefulness as low-level biochemical brain damage, and sleep as sanitary salvation. Without enough sleep, the brain is simply unable to wash away those sticky toxic proteins of beta-amyloid and tau that underlie Alzheimer's disease.

IS CAFFEINE REALLY KEEPING ME AWAKE?

One critical factor helping you fall asleep and then stay asleep across the night involves a chemical called adenosine. Think of adenosine as a sleepiness chemical. It gradually builds up in the brain throughout the day. The longer that you are awake, the more it builds up and the sleepier you feel. When concentrations of adenosine peak after 12 to 16 hours of being awake, a strong urge for sleep takes hold of most of us.

Why am I telling you this? Because you can hit the mute button on the healthy sleep signal of adenosine with caffeine. Caffeine, a psychoactive drug, races into your brain and essentially blocks the receptors for adenosine. As a result, you lose that sleepiness signal, making sleep significantly less likely to occur, and if it does, more littered with awakenings.

Caffeine concentrations peak after about 30 minutes. The problem is that caffeine persists, and for a long time. In medicine, we use the term 'half-life' when discussing a drug's impact. 'Half-life' means the amount of time it takes for your body to essentially clear away 50 per cent of the drug dose.

For most individuals, caffeine has a half-life of five to six hours. It therefore has a quarter-life of between 10 to 12 hours. So, if you have a cup of coffee at 2pm in the afternoon, 25 per cent of that caffeine can still be swirling around your brain at midnight. A coffee at 2pm would be the equivalent of tucking yourself into bed at midnight, but just before you do, you gulp down a quarter of a cup of hot coffee and hope for a good night's sleep. Which is unlikely to happen.

Please don't get me wrong. I'm not against caffeine. Indeed, coffee has been associated with numerous health benefits, though this is likely due to the powerful antioxidants within the coffee bean, not the caffeine itself. But as with many things, when it comes to caffeine, the dosage (and timing), make the poison. Limiting to one to three cups each day, and stopping that caffeine consumption by noon for most people will see you right in protecting your sleep.

WHY DO WE DREAM?

Dreaming is not simply a by-product of the sleep stage from which it emerges, called REM sleep. Instead, REM-sleep dreaming serves important benefits. Recent work in my neuroscience lab, and work of other scientists, has shown that dreams serve at least two key functions.

First is emotional first aid. It's said that time heals all wounds, but our research suggests that instead, it is time spent in dream sleep that provides emotional convalescence. Specifically, REM-sleep dreaming provides a form of overnight therapy.

Dreaming is the only time when our brain is completely devoid of the stress-related molecule called noradrenaline (the sister chemical of adrenaline). At the same time, key emotional- and memory-related structures of the brain are reactivated during REM sleep as we dream. During the act of dreaming, we are therefore able to reactivate emotional memories in a brain that's free of this key stress chemical. As a result, we get the chance to re-process upsetting memories in a safer, calmer environment.

To demonstrate this, we recently took a group of healthy adults and divided them into two groups. Both groups watched a series of emotion-inducing images inside an MRI scanner and we took snapshots of their brain activity. Twelve hours later, they came back and were shown the same emotional pictures. However, for half the participants, the 12-hour delay occurred across the same day. For the other half, that 12-hour delay took place across the night, and therefore included a full eight hours of sleep.

Those who slept between the two sessions rated the images as far less emotional the next day. This was backed up by their MRI scans, with the emotional brain centres that create painful feelings showing a significant reduction in reactivity the following day. The reason was due to a re-engagement of the more rational frontal cortex of the brain, helping dampen down these deep emotional centres. In contrast, those who remained awake across the day showed no such calming of emotional feelings or associated brain activity.

Without sleep, we therefore have too much emotional accelerator pedal, and too little emotional brake. In the study, we also measured the sleep of the

participants during that intervening night. The more time that participants spent in dream sleep, the greater the success of overnight therapy. In other words, dreaming acts like a nocturnal soothing balm, taking the sharp edges off difficult and painful experiences. As the late entrepreneur Eli Joseph Cossman delightfully noted, "the best bridge between despair and hope is a good night's sleep".

The second benefit of REM dreaming is creativity. Consider my fellow Liverpudlian, Paul McCartney. His hit songs *Yesterday* and *Let It Be* both came to him by way of REM-inspired creativity. Not to be outdone, the iconic opening guitar riff from the Rolling Stones' bestseller *Satisfaction* was also gifted to lead guitarist Keith Richards when he was asleep. We can even turn to profound scientific discoveries like the construction of the periodic table, which came to Dmitri Mendeleev during a dream.

Experiments in the laboratory have now proven such sleep-dependent creativity, resulting in innovative problem-solving abilities. Although deep non-REM sleep strengthens individual memories, it is REM sleep and dreaming when those memories can be fused and blended together in abstract and highly novel ways.

A good example of this comes from a delightful study published in the journal *Current Biology* a few years ago. Participants gradually learned to navigate a virtual maze, helped by the placement of particular objects at key places in the maze, such as a piano or a lampshade. After the learning session, the participants were assigned to two groups. One group took a 90-minute nap, the other group watched television for 90 minutes. During the nap, the researchers occasionally woke the subjects up and asked about the content of their dreams. Those watching television were also asked about thoughts going through their minds. Afterwards, the participants again tried to solve the maze.

Those who got the chance to nap were far better at navigating and solving the maze than those who stayed awake. But there was a twist. Those who slept but also reported dreaming about the maze were 10 times better at the task than those who slept but didn't dream about the maze!

How does sleep do this? We now know that during the dreaming state, your brain interconnects vast swathes of acquired knowledge. Dreaming then extracts overarching rules and commonalities. You wake up the next day with a revised mind-wide-web of associations, allowing you to establish solutions to previously impenetrable problems. Dreaming is a form of informational alchemy.

CAN SLEEP KEEP YOU SLIM?

Have you noticed a desire to eat more when your sleep becomes short? We know the reasons why. Inadequate sleep suppresses a hormone that signals food satisfaction, yet increases concentrations of the hormone ghrelin that makes you feel hungry. In spite of having eaten enough and being full, you will still want more. It is a proven recipe for weight gain in adults and children.

It's not just about hormonal changes in your body. Your brain's response to food changes when you are sleep deprived. Several years ago, my team and I scanned the brains of otherwise normal-weight individuals as they were choosing which items they wished to eat from a range of unhealthy and healthy foods. We had these participants do this twice: once after a full night of sleep, and once after being sleep-deprived for a night. The brain scans demonstrated that regions in the prefrontal cortex that sit just above your eyes, and are required for controlled decisions, had been switched off by a lack of sleep. These impulse-control regions normally keep our food desires in check. In contrast, a more primal deep-brain structure, the amygdala, which drives hedonic motivations including decadent food desires, was amplified. Indeed, when sleep-deprived, participants chose foods that contained over 600 calories more than foods that these same individuals selected when properly rested.

You can now see why a person's waistline will suffer if sleep becomes consistently short, as they may be reaching for pizza or doughnuts, rather than wholegrains or leafy greens. Worse still, if you are attempting to diet, and you don't get enough sleep while doing so, it all becomes largely futile. Up to 60 per cent of the weight you lose will come from lean muscle mass, according to a small study carried out in 2010. When you are not sleeping enough, your body becomes stingy in giving up its fat stores and becomes more than willing to give away muscle. As a result, you keep what you want to lose (fat), and lose what you want to keep (muscle).

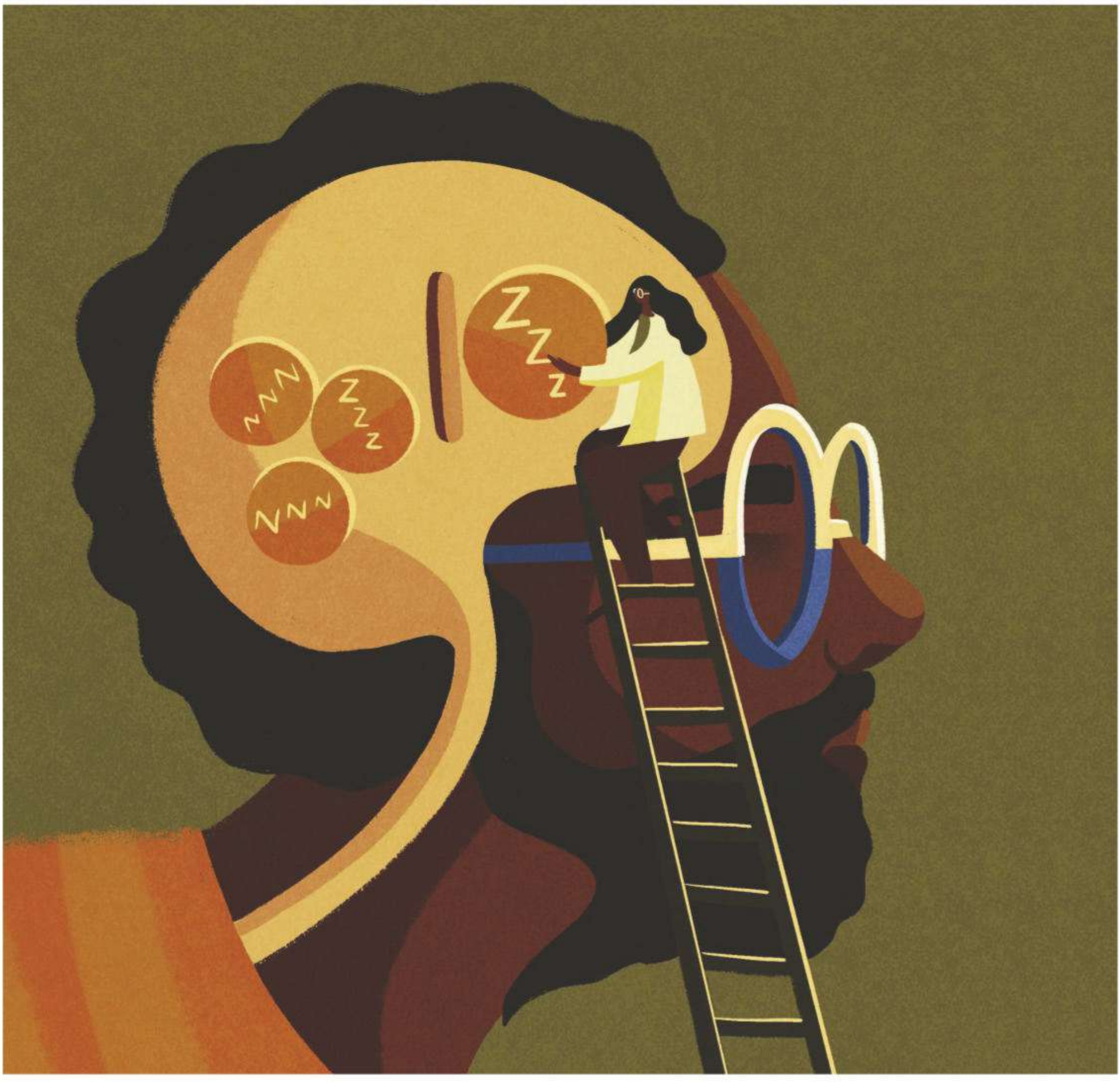
Tally all this up, and it has become increasingly clear that the silent sleep-loss epidemic may be a key contributor to the obesity epidemic afflicting so many societies, alongside the proliferation of processed foods, larger serving sizes and increased rates of sedentary behaviour. We are even observing these effects early in life. A 2005 study published in the *BMJ* found that three-year-olds sleeping just 10.5 hours or less have a 45 per cent increased risk of being obese by age seven than those who get 12 hours of sleep a night.

On a more positive note, each of us has the choice to turn the tables on all this research by cultivating better sleep habits. Prioritising sleep is one of the most powerful ways to regain control of our weight, and our waistline.

In summary, there is no major health system within your body or operation within your brain, that isn't wonderfully enhanced by sleep when you get it, or demonstrably impaired when you don't get enough.

Unfortunately, sleep is also not like the bank. Let's say I deprive you of sleep for a night (eight hours) at my Center for Human Sleep Science. Then I give you all of the recovery sleep you want on a second or even third night. While you will sleep more on those nights, you will never claim back all that slumber that you lost. Indeed, you may claim back less than 50 per cent of that missing eight hours. As a result, you will always carry that debt. In other words, you cannot accumulate a sleep debt during the week, and then hope to pay it off in full at the weekend. Try as you may, you can never get back all that you lost. Week after week, this sleep debt escalates, like compounding interest on an unpaid loan.

We should therefore think of sleep as the very best life- and health-insurance policy you could ever wish for. Thankfully, in terms of medical recommendations, it is largely painless, free, and available to pick up on repeat prescription each night, if you choose. SF



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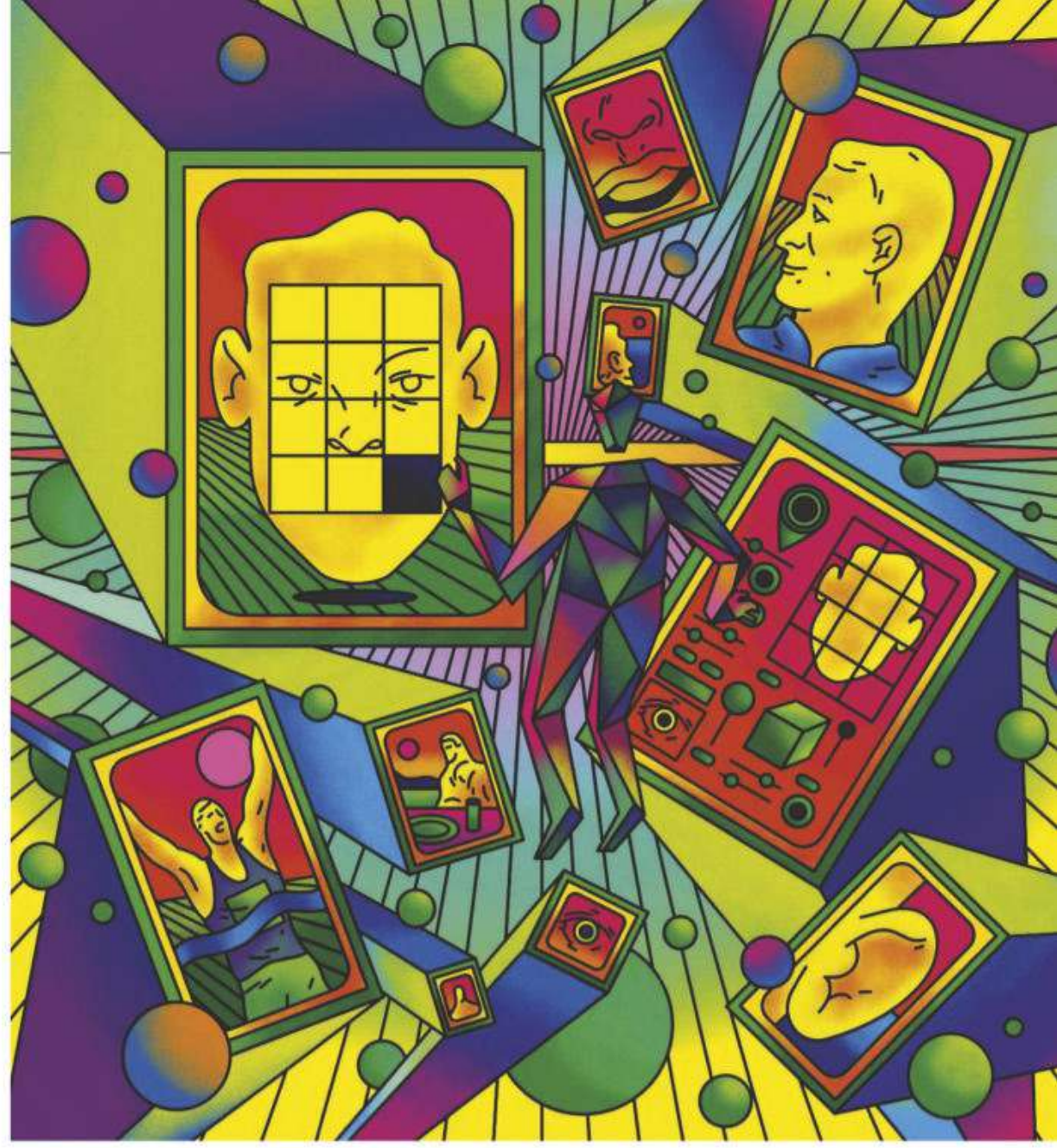
COMMENT

HIDE AND SEEK IN CYBERSPACE

A puzzle that remained unanswered for more than 14 years has now been solved, thanks to technological leaps in image searching



Since 2008, I've been trying to track down a man on the other side of the world named Satoshi. I'm not a creeper, I swear. I'm a journalist.

During the first decade of the millennium, my beat was computer games. Over my tenure, games evolved away from home consoles to weird and wonderful immersive, interactive experiences that became interlaced with the rest of our lives through the power of the internet. The most exciting were alternate reality games (ARGs), where designers created complex worlds using information already out there, or that they planted there, intertwined with codes flashed at the end of television shows, placed in magazines, or heard down the line of a public phone. The whole world could be the game board, and that made everything a bit more sparkly.

These ARGs sent players on global treasure hunts to track down daisy chains of clues that eventually led to the end of the mystery. In 2006, in a game called *Perplex City* by the British design company Mind Candy, we were sent to find a nameless man. All that we had to go on was his face on a card and a teeny bit of text in Japanese that said 'Find Me'. A hint gave the clue, 'My name is Satoshi'. The puzzle was called Billion to One

"We were sent to find a nameless man. All that we had to go on was his face on a card and a teeny bit of text in Japanese that said 'Find Me'"

– find one person out of a billion on the planet.

Writer and puzzle designer Laura E Hall set up the website FindSatoshi.com in 2006 to collect theories and clues about Satoshi's whereabouts from hunters around the world, and occasionally she'd pop up on the news or in YouTube videos trying to get more people involved. There was no other way to do it. Classic six degrees of separation stuff.

Satoshi was found last year, and according to Laura, it was only possible to identify him because of a recent shift in technology. "For the first few years, all we could do is get the word out to as wide a network as possible," she explained in the recent 'Find' episode of *The Digital Human*. From 2018, it became possible for artificial intelligences to search for faces in a different way than ever before. These new techniques are based on facial recognition that can identify the same person in different photos, at different times. Previously, if you wanted to search for an image, the algorithm would find where on the web the same image you searched for also lived.

The last time Laura appeared on a YouTube vid about unsolved mysteries in 2020, a man named Tom-Lucas Säger in Germany took the bait. He did a reverse image search, found a picture of a guy who looked like Satoshi, cross-referenced it with a photo of a runner at the finish line of a Japanese marathon that had been uploaded a year or so earlier, and found out with a simple search that this runner's name was Satoshi, and voila, the mystery was solved.

When Laura contacted him, Satoshi Shimojima had forgotten that he'd once donated a photo to a random stranger who was making a game. He's just an ordinary guy who lives in Japan. But tens of thousands of people had been searching for him since that time. All it took was technology to catch up and solve the mystery. SF

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *The Digital Human*.

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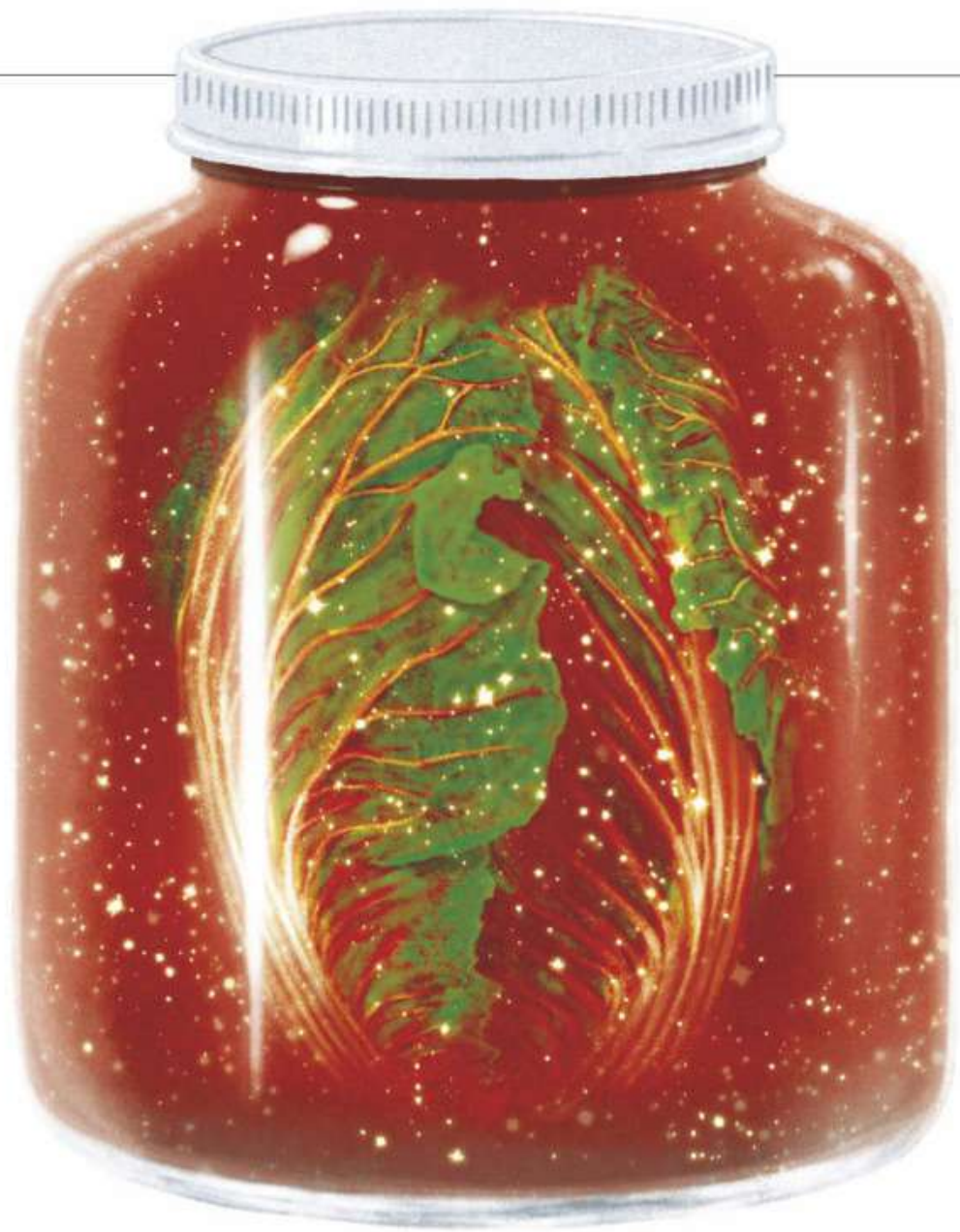

Listen to Michael's new podcast series *Just One Thing*. Each episode suggests an effective way to improve your wellbeing in one simple step. Available on BBC Sounds.

COMMENT

FOR GUT'S SAKE

Gut-boosting foods are popping up on supermarket shelves, but are they more than just a trendy side dish?

Although fermented foods like kimchi and sauerkraut have been around for hundreds of years, and were traditionally just a way to help preserve vegetables over the long winter months, in recent times they have become super trendy. I like making and eating my own fermented foods, but what is the evidence that they do you any good?

The current excitement is based largely on the impact that eating fermented foods has on your gut microbiome – the trillions of microbes that live in your gut and which have a profound impact on our health.

One way to influence your microbiome is to eat foods that are rich in prebiotics and probiotics. Prebiotics are, broadly speaking, fibre and other nutrients that our microbiome likes to feast on and which confer health benefits. Probiotics, on the other hands, are living microbes in food which, when eaten, bolster the armies of 'good' bacteria living in your gut.

Fermented foods, like sauerkraut and kimchi, are rich in both prebiotics and probiotics, or at least they are if you make them yourself, which I do. The bottles of fermented vegetables you buy in supermarkets are often pasteurised, so any living bacteria are now long dead.

Kimchi is a Korean dish, made of cabbage, seasoned with chilli, garlic and ginger, and then fermented. It is rich in vitamin K and riboflavin (B2) and also contains plenty of *Lactobacillus* bacteria, which can survive the acid bath of the stomach and make their way down to your large intestine.

In a small study carried out a few years ago by Korean researchers ('Beneficial effects of fresh and fermented kimchi in prediabetic individuals'), 21 patients with prediabetes were asked to either eat fresh (1-day-old) or fermented (10-day-old) kimchi for eight weeks. Then, after a four-week washout, they switched to the other form of kimchi for the next eight weeks. Eating either type of kimchi led to a significant reduction in weight and waist size, but it was only when the patients were eating the fermented stuff that they saw significant improvements in blood pressure and insulin sensitivity, suggesting the *Lactobacillus* were doing something.

"Eating either type of kimchi led to a reduction in weight and waist size"

Like kimchi, sauerkraut is based on fermenting cabbage. Despite being associated with German cuisine, it almost certainly originated in China more than 2,000 years ago. Sauerkraut is packed with vitamins and minerals, including iron, potassium, copper and manganese. It is also low in calories and rich in fibre, which your microbiome will enjoy. That said, I couldn't find any specific human studies showing that eating sauerkraut leads to particular benefits. The alleged benefits are mainly based on animal studies.

Nonetheless I am a huge fan of fermented cabbage, and eat a good dollop of either homemade kimchi or sauerkraut most days. One word of warning: if you decide to do the same, ease your way in. If your guts are not used to fermented food then they may react badly to a sudden invasion of a vast army of foreign microbes with bloating, stomach cramps or wind. SF

MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *COVID-19: Everything You Need To Know About Coronavirus And The Race For The Vaccine* (£6.99, Short Books).

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LOOT BOXES

THE NEXT BIG BATTLEFRONT

ALAMY

Periodically, there have been moral panics about video games, with headlines claiming that "violent" and "addictive" titles are affecting impressionable players. At present, it is loot boxes' turn to be put under the microscope. But should we be worried about video games, and are loot boxes a cause for concern?

by **DR PETE ETCHELLS**

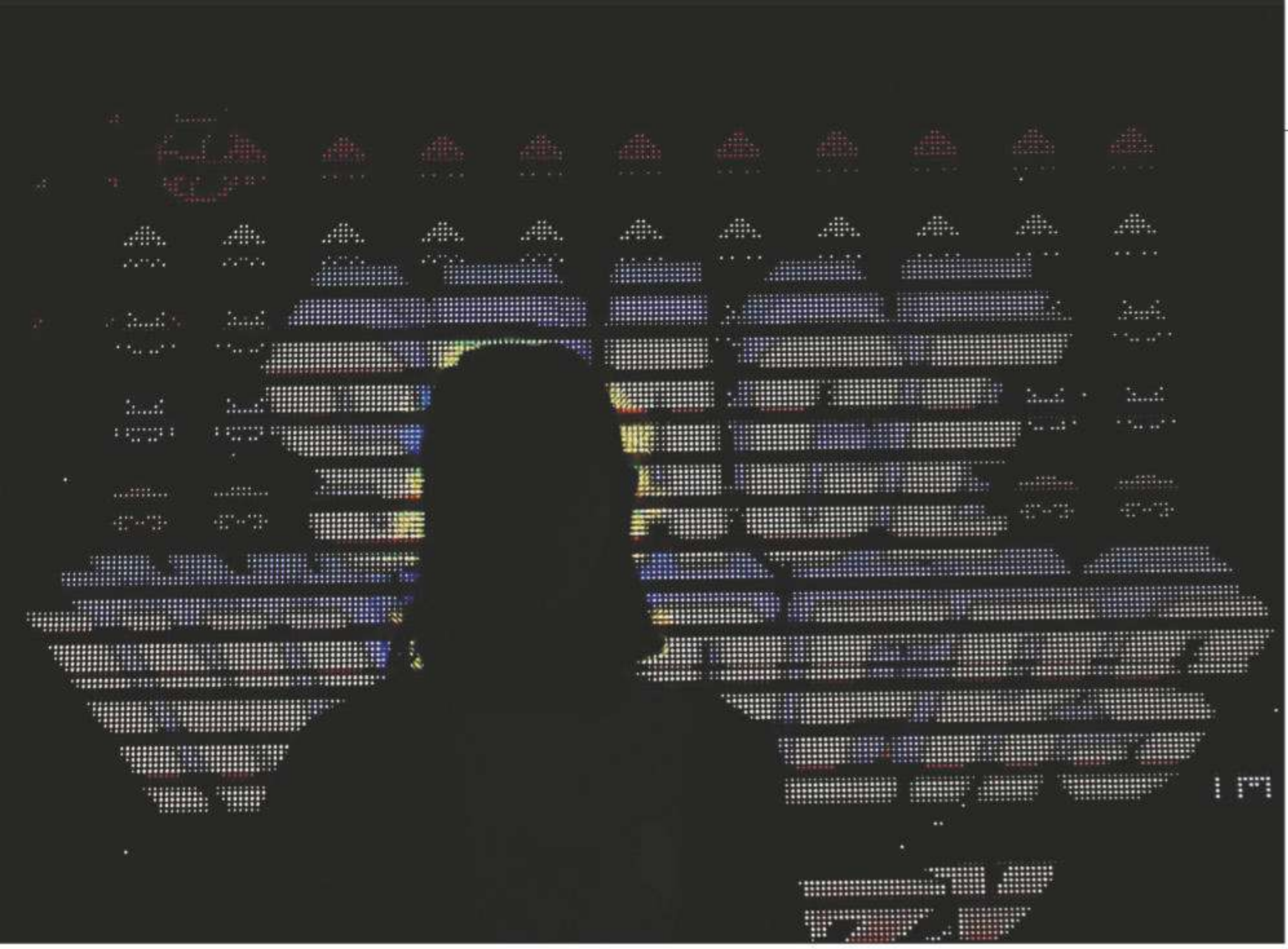
For nearly as long as video games have been around, society has had worries about their potentially addictive nature. It's understandable, in a sense – to the untrained eye, watching people play video games can often be an unnerving experience. Players look like they're glued to their screens, fully absorbed and seemingly unaware of what's going on around them. If you don't have lived experience of the rich and varied social environments that video games can afford, it's easy to see them as an unwholesome activity that can't be good for us.

In the early 1980s, this distrust went so far as to be a subject of debate in the UK House of Commons. 'Control of *Space Invaders* and other electronic games' was a bill put forward by then-MP George Foulkes, and he held no punches in his beliefs about the effects the game had. "I have seen reports from all over the country of young people becoming so addicted to these machines that they resort to theft, blackmail and vice to obtain money to satisfy their addiction… They become crazed, with eyes glazed, oblivious to everything around them, as they play the machines," he said.

GAMING ADDICTION

Foulkes's bill never passed, but the fears around video games remained. In 1982, a year after the Commons debate, a letter appeared in the *Journal Of The American Medical Association* titled '*Space Invaders* obsession'. In it, researchers based at Duke University Medical Center flagged an apparent psychiatric complication of playing the game – three men, aged between 25 and 35, were reported to have become, well, obsessed with the game, vastly upping the amount of time they were playing it in the weeks leading up to each of their marriages. In the letter, the researchers suggested, bizarrely, that the fixation came about because the men were struggling to deal with their 'anger' over their impending nuptials. "The disintegration of invading aliens who were trying to overrun the 'home base' took on symbolic significance" they breathlessly argued, in what appears to be a damning indictment of wedlock.

Space Invaders took the centre stage in these concerns because it was the big hit of the era. Since then, each time



Over the decades, headlines have accused video games of being addictive or causing violent behaviour

we've gone through a cycle of worries about the potential negative effects of video games, they've largely been pinned to the most popular titles of the moment. In the 1990s, it was games like *Doom* and *Mortal Kombat* that fuelled fears of violent video games causing aggression. Then it was first-person shooters like *Call Of Duty*. In 2018, when the World Health Organization announced that it was including 'gaming disorder' as a formal addictive behaviour in its International Classification of Diseases (ICD-11), it was worldwide success *Fortnite* that took the brunt of the news stories about gaming addiction – headlines such as "*Fortnite* addiction now a recognised mental health disorder", and "Children hooked on *Fortnite* will be treated on the NHS for addiction" came to the fore as journalists scrabbled to put the WHO's decision in context.

As is always the case, what the headlines claim and what the actual research suggests are two different stories. Now, more than two years later, scientists are still in disagreement about what gaming addiction actually looks like, how best to diagnose it, and how many people it might affect. And there's certainly no evidence to suggest that specific games, like *Fortnite* now, or *Space Invaders* then, are more or less addictive. In fact, that goes to heart of one of the fundamental problems of research in the area: by and large, research takes a macro-level view of video games effects, treating them as a singular entity – or at best, segregating them based on genre categorisations that often don't fully capture the breadth and variety of experiences that games can afford us.

World Of Warcraft is a classic example of this. The 16-year-old massively multiplayer online role-playing game has often cropped up in news stories about violent video games, and while that categorisation is in some sense true – much of the game involves fighting hordes of monsters and demons – it's also a game that, among other things, allows you to tend to gardens, socialise with friends, help other players out with difficult quests, or collect a vast array of pets and riding mounts. A popular yearly event in-game is 'the running of the gnomes', whereby the community gathers together to create new gnomish characters, replete with pink hair and beards, who then run across the world en-masse to raise money for breast cancer awareness. Is it a violent game? In some ways, yes. In most ways, not really, which makes it hard to neatly categorise when it comes to assessing the potential positive and negative effects of game play.

OPEN THE BOX

Over the past few years, researchers have started to come to the realisation that, rather than focus on video games as a homogeneous group, it's more useful to look at how specific mechanisms that are implemented within them might have more testable effects. And, given the general worries about video game addiction that have been a mainstay of public discussions about them, the most prominent mechanism that has drawn attention is how games have become increasingly monetised through in-game microtransactions. Specifically, scientists – and policymakers – have started to become interested in loot boxes.

Loot boxes, if you've never come across them before, are essentially the digital equivalent of

ALAMY X2

"LOOT BOXES LOOK A LOT LIKE GAMBLING – YOU PAY MONEY TO GET A CHANCE AT SOMETHING YOU WANT"

those football sticker packs we used to collect when we were younger. In a given game, you have the opportunity to open a box (or a pack of cards, or spin a wheel) that contains a random selection of items that can be used in play. The specific form that these items take varies – in some games, you might get the chance at a new costume for a character, whereas in others you might get new powers that give you an in-game advantage – but the principle is largely the same across formats. Some of the items will appear frequently, be of relatively low value, and therefore not particularly desirable. Other items are much rarer, offering more powerful benefits or fancier costumes, and therefore more covetable. Where some games offer you free boxes after completing certain tasks – say, after levelling up your character – most also offer you the option to buy additional boxes for cash, and it's this possibility that has some scientists concerned.

GAME-BLING PROBLEM

In many ways, loot boxes look a lot like gambling – you pay some money to get an (often undisclosed) chance at something you really want. The more you pay, the more likely you are to 'win', but there's never a 100 per cent guarantee. And an emerging body of research is starting to show that there are associations between the way that loot boxes are implemented in games, the extent to which players buy them, and issues in terms of problematic gambling behaviours and mental wellbeing. It's early days for this area of study, but all of the papers published on loot boxes so far seem to show the same patterns: greater levels of loot box purchases seem to be positively correlated with increasing levels of problematic gambling.

For example, recent work led by Dr David Zendle at the University of York surveyed 1,200 participants, and asked them to complete various questions about their online gaming habits, the types of loot boxes they encounter in the games they play, as well as a questionnaire about problematic gambling habits. The overall take-home message from the study was that regardless of how loot boxes are implemented, if you pay for them, there was a relationship with levels of problem gambling – about 9 per cent of the variation in these levels could be accounted for by purchase behaviours. That effect became stronger or weaker depending on the specifics of the mechanism: for example, some games use a 'near miss' strategy (akin to those seen in slot machines), showing players what they could have won but just missed out on. That seemed to show the strongest effect, whereas for games in which the items players could win didn't offer any in-game advantage (such as character outfits), the effect was weaker.

This finding, that paying for loot boxes correlates with higher levels of problem gambling behaviours, is one that we see in a wealth of other studies in the area, and has in part resulted in a drive to revise the UK Gambling Act to better regulate such mechanisms in games. The argument goes that although these studies don't show a causal relationship between loot box spending and problem gambling, in a sense it doesn't matter, because either direction is cause for concern. Either it's the case that paying for loot boxes acts as a 'gateway' and causes people to develop problem gambling behaviours, or it's that people who are already disposed to disordered gambling are more drawn to games that contain loot boxes, in which case vulnerable individuals are being inappropriately exploited.

That's a reasonable starting position to take, but we have to be careful here. Video games research has a long history of starting from a situation in which exploratory studies using methods that have significant limitations all converge on a similar finding, which then drives public concern ➲

about the seemingly negative effects of playing games. In turn, this forms a focal point for policymakers to want to enact legislation restricting their use in some way. Much later down the line, when we start to get stronger studies using much more robust methods, we start to see a very different line of evidence come through, one which lies counter to the prevailing belief about the effects of games. Perhaps the most well-known example in the cycle of moral panics driven by ill-thought-out research is that of the debate around so-called violent video games.

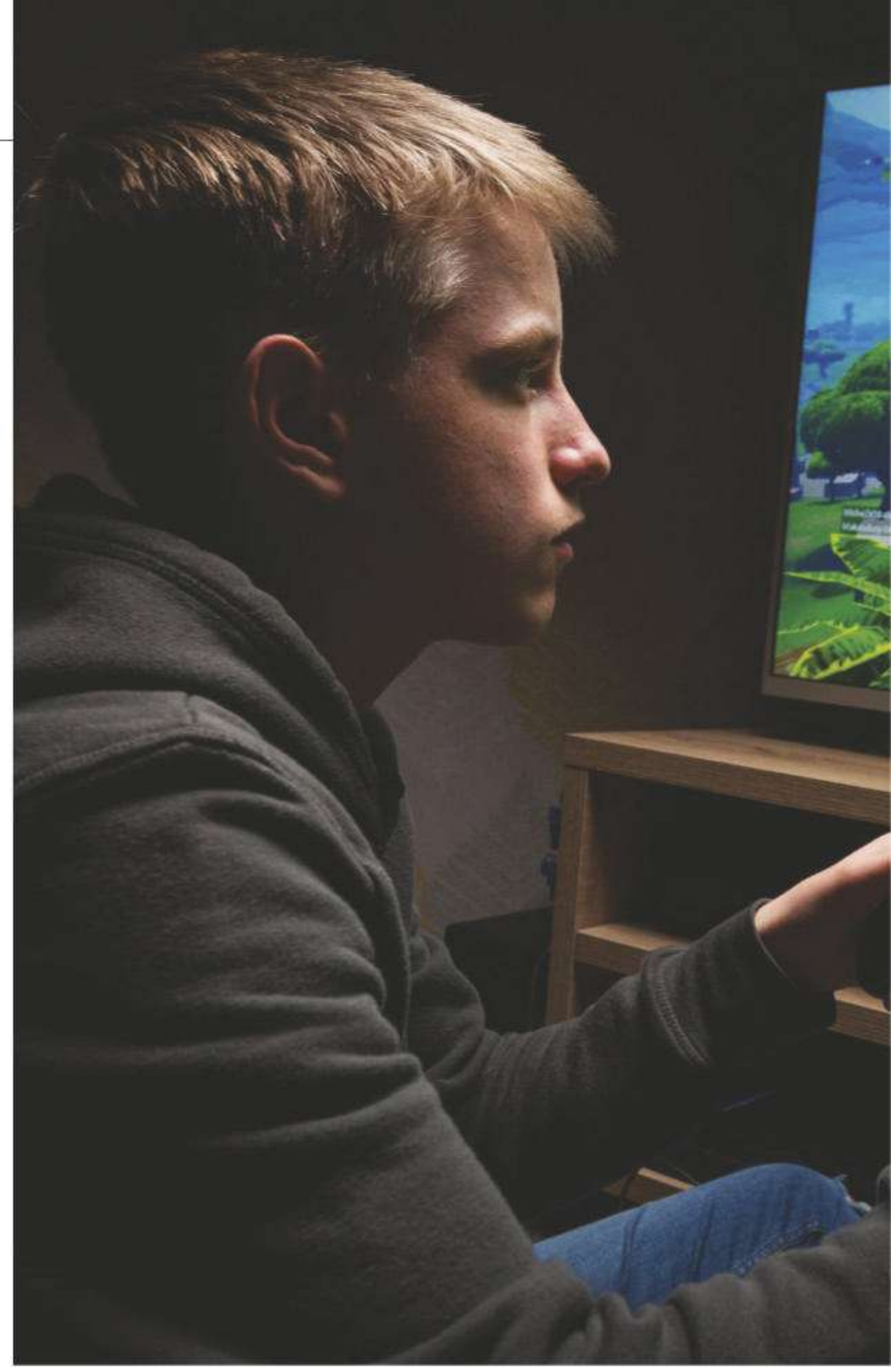
For decades, a vast literature built up which appeared to show evidence that playing violent video games caused increases in aggressive behaviour in young people. The methods used to assess aggressive behaviour were extremely poor – it's hard to convincingly test for truly aggressive behaviours in the lab. Nevertheless, the idea that games like *World Of Warcraft*, *Call Of Duty* and *Doom* could drive teenagers to acts of violence took hold in the public psyche, driving, among other things, congressional debates about them in the US Senate. But as scientists started to implement better tools to assess this question, it turned out that although there might be a link between playing violent video games at a young age and later aggressive behaviours, the associations are small, and not really worth worrying about. And yet we still see a cycle of news articles every few months or so which perpetuate the idea that 'violent' games are demonstrably negative in their impact on us. It's an idea that will still take time to turn around.

GET IT RIGHT

Loot box research, thankfully, doesn't suffer from the same fundamental issues that plagued work on violent video games; in fact, it's an area of study where we see real attempts to get the science right. Much of the work in this area adheres to the principles of open science: scientists pre-specify how they are going to collect data and how they plan on analysing before the start of their studies, in order to protect against the risk of fishing for results that show a particular effect.

Nevertheless, given that most of the literature relies on correlational findings, we're not yet at a stage where we can say with any conviction that, for the majority of gamers, loot boxes pose a clear problem that we need to do something about. For example, a recent study by a team led by Dr Aaron Drummond at Massey University in New Zealand again showed a positive correlation between loot box spending and problem gambling, but the absolute effect was small – on average, those with problematic gambling behaviours spent about $13 (£9 approx) more than those without symptoms. Moreover, loot box spending seemed to be correlated with both negative and positive moods, suggesting that the relationship with mental wellbeing is a complex one that we need more time to unpack.

In order to address some of these gaps in our current understanding, I've recently launched a survey to look in more detail at the relationship between loot box spending, more general digital spending, gambling and gaming behaviours,



"LOOT BOX SPENDING SEEMED TO BE CORRELATED WITH BOTH NEGATIVE AND POSITIVE MOODS, SUGGESTING THAT THE RELATIONSHIP WITH MENTAL WELLBEING IS COMPLEX"

ALAMY, MASSEY UNIVERSITY

If you are aged 18 or over, have played a game containing a loot box mechanic over the past month, and would like to take part in research mentioned in this article, you can find the survey here: **bathspa.onlinesurveys.ac.uk/loot-boxes-mental-health**

ABOVE RIGHT Dr Aaron Drummond has found a positive association between loot box spending and problem gambling, but the effect is small

ABOVE *Fortnite* has taken the brunt of accusations about addiction in recent years

and mental wellbeing. It won't fix all of the issues described above, but the hope is that beyond simply finding correlations between these sorts of factors, we can also look at the strengths of those associations, and ultimately take a further step down the road to getting a strong evidence base.

And before we start thinking about regulating loot boxes, a strong evidence base is just what we need – one which, ideally, uses objective measures of spending behaviours, as well as stronger measures of mental health and gambling behaviours. In order to do that, we need to get the games industry on board, as they hold the data that is key to understanding how games impact our lives. Only by precisely looking at what games people are actually playing (and for how long), and how much they are spending, can we start to really get an idea of whether there's a problem with loot boxes, and what sort of gamers they pose a problem for.

If we want the games industry to be open to the idea of sharing data and working collaboratively with independent researchers, we need to avoid a moral panic around loot boxes. As we've seen before, to do so would drive the public discourse around them into unhelpfully simplistic narratives about them being nothing but bad news, and could easily result in games developers disengaging from the conversation. In turn, we risk walking down the path that we saw with the violent video games debate; wasting time and energy driving policy decisions in the wrong direction, and finding it difficult to turn the public narrative about video games around when we finally, years down the line, get data that actually speaks to their true effects. For that reason, all of us – scientists, policymakers, journalists and the public at large – need to maintain a level head and a sense of responsible uncertainty.

Loot boxes may turn out to be a real detriment to our mental health, or in time it may become apparent that they aren't as big an issue as they initially seemed. For now, it's okay to admit that we don't know what the real impact of spending money on them is. The science will get there; we just need to give it a chance. **SF**

by **DR PETE ETCHELLS**

Pete is a professor of psychology and science communication at Bath Spa University. He is currently researching the short- and long-term behavioural effects of playing video games. He is the author of Lost In A Good Game *(£9.99, Icon Books).*

An unknown species, possibly pangolins, may have played a part in the spread of SARS-CoV-2 to humans

GETTY IMAGES

HOW WILDLIFE VACCINES WILL PREVENT THE NEXT HUMAN PANDEMIC

The coronavirus vaccines currently being injected into arms across the world are our escape route to normality. But keeping deadly viruses at bay and maintaining our freedoms in the future may require brand-new mass vaccination programmes that look very different to the ones currently taking place

by ANDY RIDGWAY

The coronavirus SARS-CoV-2 that has dominated the news since early 2020 has something in common with other diseases that have hit the headlines in recent years. SARS-CoV-2, just like Ebola, HIV and MERS before it, originated in wildlife before 'spilling over' into humans. SARS-CoV-2 currently appears to have originated in horseshoe bats and was potentially transferred to humans via an unknown species, possibly pangolins. But other so-called zoonotic diseases (illnesses that spread from animals to humans, and vice versa) originated in the likes of chimps, camels and mice.

While the existence of zoonotic diseases has been known for decades, the coronavirus pandemic has brought into sharp focus how closely our health is connected to the health of the animal species with which we come into contact. "This pandemic is just a tragic wake-up call," says epidemiologist Dr Jonna Mazet at the University of California, Davis.

Mazet was principal investigator on the PREDICT project, a $207m (£150m approx) global effort run from the US to build a clearer picture of the viruses lurking in wild animals that could spill over into humans and wreak havoc. From 2009 to 2019, the project's scientists collected samples of animal blood, saliva and dung from fields and forests in 30 countries. They found 940 virus species that hadn't been previously identified, including 160 coronaviruses and one new Ebola virus that were previously unknown. But this may just be the tip of the iceberg. "We estimate there are probably about 500,000 viruses that could infect people that have not been characterised or detected by science," says Mazet. Not all of these would cause disease, but it shows the scale of the problem.

Combine the number of viruses capable of spilling over into humans with deforestation, bushmeat hunting, and farming activities encroaching into wildlife-rich areas, and it's a dangerous cocktail. It's no wonder then that the US Centers for Disease Control and Prevention (CDC) estimates that 75 per cent of the new or emerging infectious diseases we are contending with originated in animals.

TOO CLOSE FOR COMFORT

A clear demonstration of the close connection between human and animal health came in June 2020, during the first months of the pandemic. Danish authorities reported that SARS-CoV-2 had leapt from humans to mink and spread extensively on mink farms. Not only that, but the virus also jumped back to humans, causing a spike in the country's coronavirus cases. What was particularly worrying was that some of those who caught coronavirus from mink had a new virus variant. Thankfully, tests showed that the variant's mutations did not make it more contagious or deadly. SARS-CoV-2 has also been detected in a raft of other species that humans come into contact with, including gorillas at San Diego Zoo Safari Park and a snow leopard at Louisville Zoo.

"75 per cent of the new or emerging infectious diseases we are contending with originated in animals"

Dr Kaitlin Sawatzki, a postdoctoral researcher at Tufts University in Massachusetts, has been testing pets brought into a veterinary clinic to see whether any of them picked up SARS-CoV-2 from their owners. While Sawatzki is reticent to say how many of the dogs and cats tested positive for coronavirus antibodies before

ABOVE The SARS-CoV-2 virus may have originated in horseshoe bats

the research is published, she says that what she found was "comparable" with an Italian study of pets from 2020 in which 3 per cent of dogs and nearly 6 per cent of cats tested positive. The good news is that dogs don't appear to get ill with SARS-CoV-2, and for cats it may only cause a mild illness.

"As far as domestic pets go, I don't think those are going to play any real role in a public health concern," says Sawatzki. "But if we're thinking of the bigger picture here, other than the gorillas, all of the animals that we've seen these accidental transmissions in have been carnivores. So I'm concerned about wild carnivores and the potential for them to be infected and then for reverse transmission back into humans."

ABOVE LEFT Mink farms in Denmark were instructed to kill all their animals after the coronavirus was reported to have jumped from humans to mink and then back again

ABOVE RIGHT This very good boy is having his nose swabbed as part of a study to see whether pets can pick up SARS-CoV-2 from their owners

A NEW VACCINE?

It's for situations like this that The Vaccine Group (TVG), a spin-out company at the University of Plymouth, is currently developing a new SARS-CoV-2 vaccine that could be injected into animals as well as humans. The vaccine uses a benign virus, bovine herpesvirus 4, that acts as a carrier for genetic material from SARS-CoV-2.

What makes bovine herpesvirus 4 particularly useful as a virus vector is that it can harmlessly infect many different animal species, making it a flexible vaccine that could be injected quickly if an outbreak cropped up in a new animal species that humans come into close contact with. It is being prepared for the unexpected that's important. "We can get a feel for where SARS-CoV-2 is going, but it can always surprise," says Dr Michael Jarvis, associate professor in virology and immunology and TVG's chief scientific officer.

Rather than just carrying genetic material for the virus's protein spike, like the current vaccines do, this new vaccine also contains genetic material from the shell that surrounds the virus's genetic material as well as its outer membrane. These parts of the virus don't change between variants, so the vaccine can provide protection against them. If tests in pigs show the vaccine is effective in generating an immune response, it would soon be ready and waiting for another coronavirus outbreak in animals and, with further testing, could be used as a new variant-proof vaccine for humans. Russia's state veterinary service also announced that it has developed a SARS-CoV-2 vaccine for animals, but few details have been provided about what form it takes.

There's a snag. Vaccinating wild animals to prevent 'spillovers' of viruses – whether it's SARS-CoV-2 transferring back into humans, or a new coronavirus or a new Ebola – is a massive logistical challenge because of the sheer number of animals involved. But what if rather than having to inject every single animal, the vaccine could spread itself? It's an idea that's gathering momentum. "My impression is probably biased but interest in self-disseminating vaccines has grown exponentially over the last few years," says Prof Scott Nuismer, an expert in self-disseminating vaccines at the University of Idaho.

One approach being explored is to have a 'transferable vaccine' that is painted onto the fur of a handful of bats, mice or any other species in a population. Then, when their neighbours lick them during grooming, they ingest the vaccine and become immune. Such a vaccine that could provide vampire bats with immunity to rabies has already been trialled by researchers at the University of Glasgow (See 'Vaccines for vampires,' overleaf).

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VACCINES FOR VAMPIRES

Vampire bats (*Desmondus rotundus*) have a nasty habit of living up to their name, biting livestock and even humans to lap up their blood as a meal. The trouble is, they carry rabies. This makes them a prime target for a wildlife vaccination campaign where they hang out in Central and South America.

A transferable rabies vaccine that can be painted on and passed between animals is in development. So researchers led by Dr Daniel Streicker, a senior research fellow at the University of Glasgow, have been testing how effectively a painted-on vaccine would spread between vampire bats by using a fluorescent marker painted on the backs of bats in Peru. The results are promising, showing a painted-on vaccine would be three times more effective at making the bats immune to rabies than traditional vaccines. "I think application of transferable vaccines will become achievable relatively soon, at least in small scale experimental contexts," says Streicker.

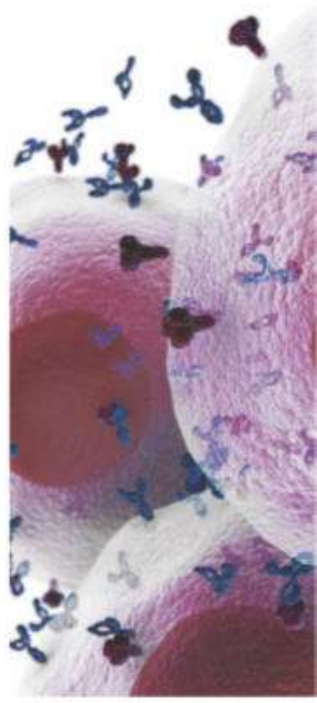
But a vaccine that would be contagious and harmlessly 'infect' vampire bats after a handful are injected could vaccinate many more bats and so holds more promise in the longer term. So far, Streicker and his team have focused their efforts on identifying a harmless virus specific to vampire bats that could be engineered to be a viral vector, carrying a payload of part of the rabies virus. And they have found one. After conducting metagenomic sequencing of the viruses in bat saliva and faeces collected in Peru, they found bat betaherpesvirus. Streicker says this virus looks like a "very strong candidate" to be a vector. The next step is to study how this virus spreads in wild and captive vampire bats. "If a transmissible vaccine were able to naturally spread to inaccessible or unknown bat populations, that would be game changing," says Streicker.

"MERS, SARS, SARS-CoV-2 haven't been separated by much time. I don't see any reason to think there won't be another one in the next 10 or 20 years"

"Technologically we're almost there with transferable vaccines, the final challenge is just fine-tuning the delivery system in a way that encourages a mouse or fruit bat to lick their friends and ingest the vaccine," says Nuismer. The big drawback of transferable vaccines is that the vaccine pasted onto each bat or mouse will only spread so far. Far more effective is a 'transmissible vaccine' that could spread indefinitely. Here a bat or a mouse, or whatever the virus reservoir species is, would be injected with the vaccine, passing it on to its neighbours by harmless infection, which then pass it on to its neighbours and so on. Researchers at Jarvis's lab at Plymouth are already on the case and are currently developing a transmissible Ebola vaccine for apes and bats, and another for Lassa virus in rats.

RISK MANAGEMENT

While transmissible vaccines are further off, it's worth thinking of the risks. For starters, what if the virus used in the vaccine mutates back into its original form capable of causing the disease? The solution, says Nuismer, is to not use an attenuated vaccine in which the virus largely remains intact. A safer alternative is to use a recombinant vector – a benign virus that doesn't



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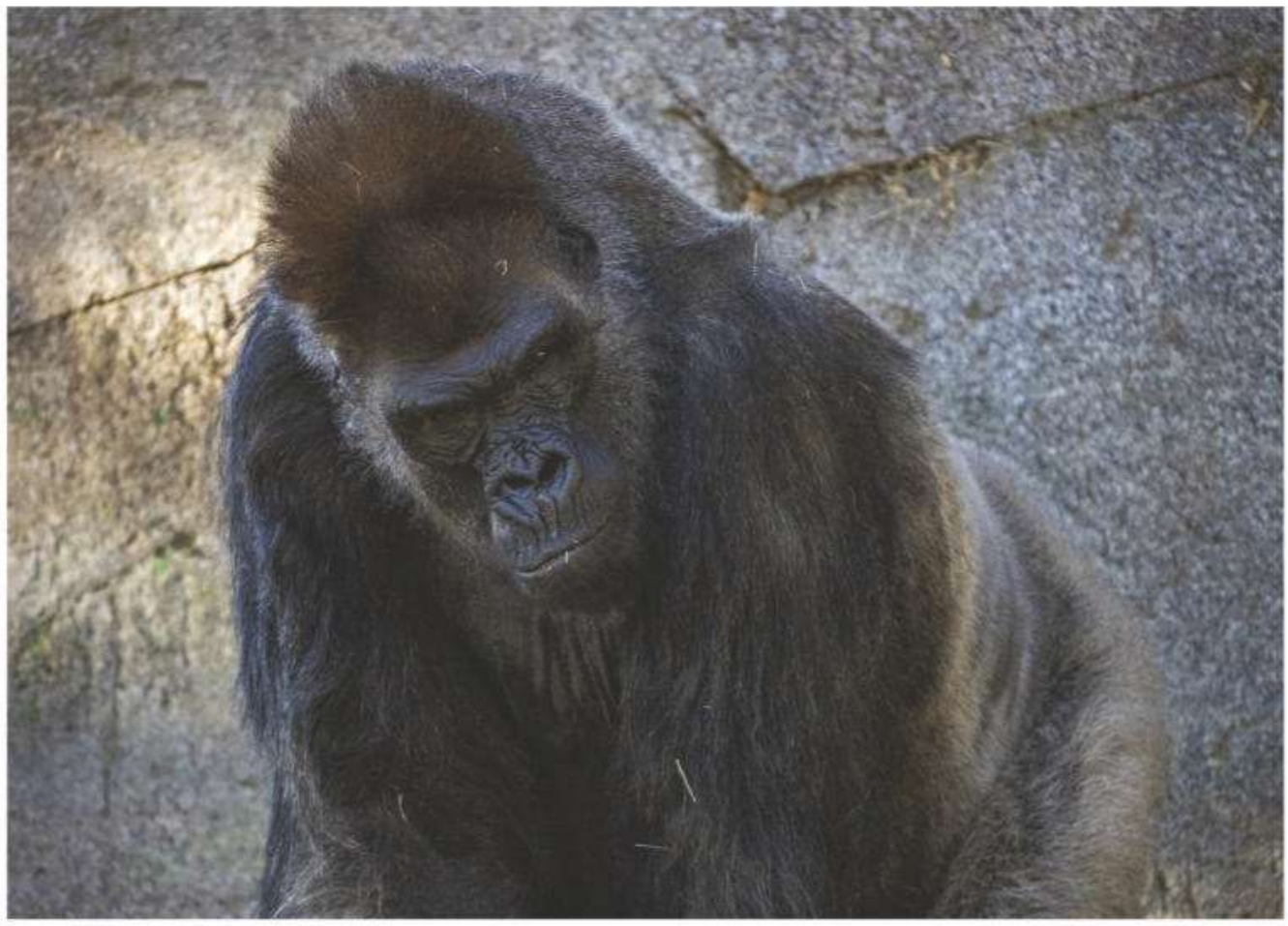

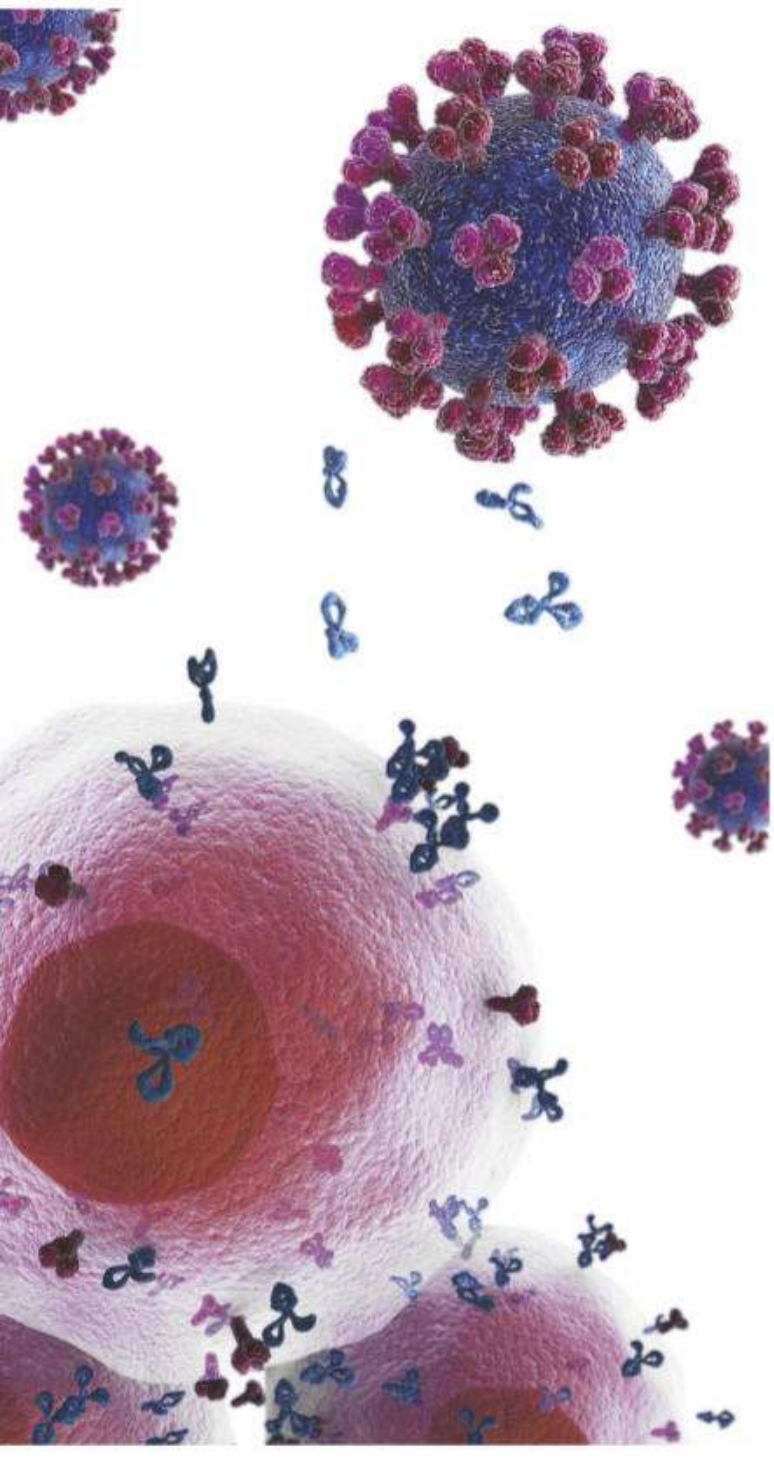

ABOVE LEFT Dr Michael Jarvis and his team are working on a new coronavirus vaccine that could be injected into animals as well as humans

ABOVE RIGHT Winston, along with members of his troop at San Diego Zoo Safari Park, contracted SARS-CoV-2 in early 2021

LEFT Visualisation of the immune response to a COVID-19 vaccine, with the body's cells (pink, bottom) producing viral spike proteins. The immune system will recognise these as foreign and will be able to produce antibodies if future SARS-CoV-2 (dark blue, top) infections occur

by **ANDY RIDGWAY**
@AndyRidgway1
Andy is a freelance science writer based in Bristol.

cause disease and so can't go rogue. Into this, a small amount of genetic material from the disease-causing virus is added to stimulate an immune response. "Then it bounces from individual to individual, transmitting that wild virus and it immunises as it goes," says Nuismer. "Everything I know as an evolutionary biologist suggests that this idea of putting this gene in and having it turn into some monster virus that kills us all seems *extremely* unlikely." This vector would need to be specific to the species it's inoculating to prevent the vaccine spreading uncontrollably to different species – species in which no trials have been conducted to ensure it's not harmful.

Then there's one final risk – that eradicating one virus by vaccination would leave the door open to another that's more dangerous. "If you go into a wildlife population and you knock out one virus, do you create an empty niche that can be invaded by some other virus that wasn't a problem before? We know this from non-viral ecology – if you destroy an area, you're going to get invasive species," says Nuismer. To rule this out, a transmissible vaccine would need to be tested on small groups of animals to check that no new harmful viruses creep in.

But before pre-emptive wildlife vaccination programmes can be an effective way to prevent the next pandemic, we need a *much* clearer view of the viruses lurking out there. In recognition of the need to do more to combat zoonotic diseases, in September 2020 the US government agency USAID announced a new $100m (£73m approx) project, STOP Spillover, to try to detect spillover events more rapidly and develop new ways of containing them.

Even just looking at the coronaviruses, there's a clear case for prioritising wildlife vaccines. "MERS, SARS, SARS-CoV-2 haven't been separated by much time in the grand scheme of things. I don't see any reason to think there won't be another one in the next 10 or 20 years," says Nuismer. But before the vaccines can be developed, we need to know more about which species coronaviruses live in and whether they bounce between different species. "The first step is to get out there and figure out what are these things actually doing." **SF**

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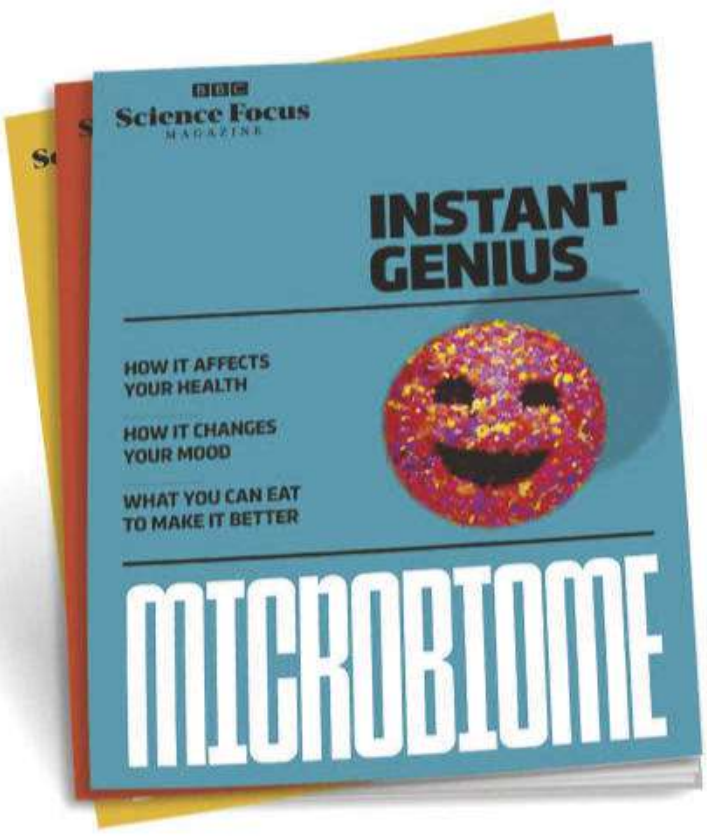

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... DO WE GET OUR GUT BACTERIA BEFORE OR AFTER BIRTH?
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ILLUSTRATION: DANIEL BRIGHT

YASMIN HAYES (AGE 15), LONDON

DOES BLOOD REALLY COME OUT OF YOUR MOUTH IF YOU GET SHOT?

Like with most of Hollywood, it's possible – but not likely to the degree you see in films.

In theory, an abdominal wound could cause someone to vomit up blood (known as haematemesis). But usually the bleeding happens internally, and pools in the cavity of the abdomen. Similarly, bleeding in the lungs from a wound might cause a person to cough up blood (known as haemoptysis). Trauma in the mouth might also make someone spit blood.

But the violent, gravity-defying blood spurts you see in movies are simply for dramatic effect, and not very realistic. ***NM***

DEAR DOCTOR...

HEALTH ISSUES DEALT WITH BY *SCIENCE FOCUS* EXPERTS

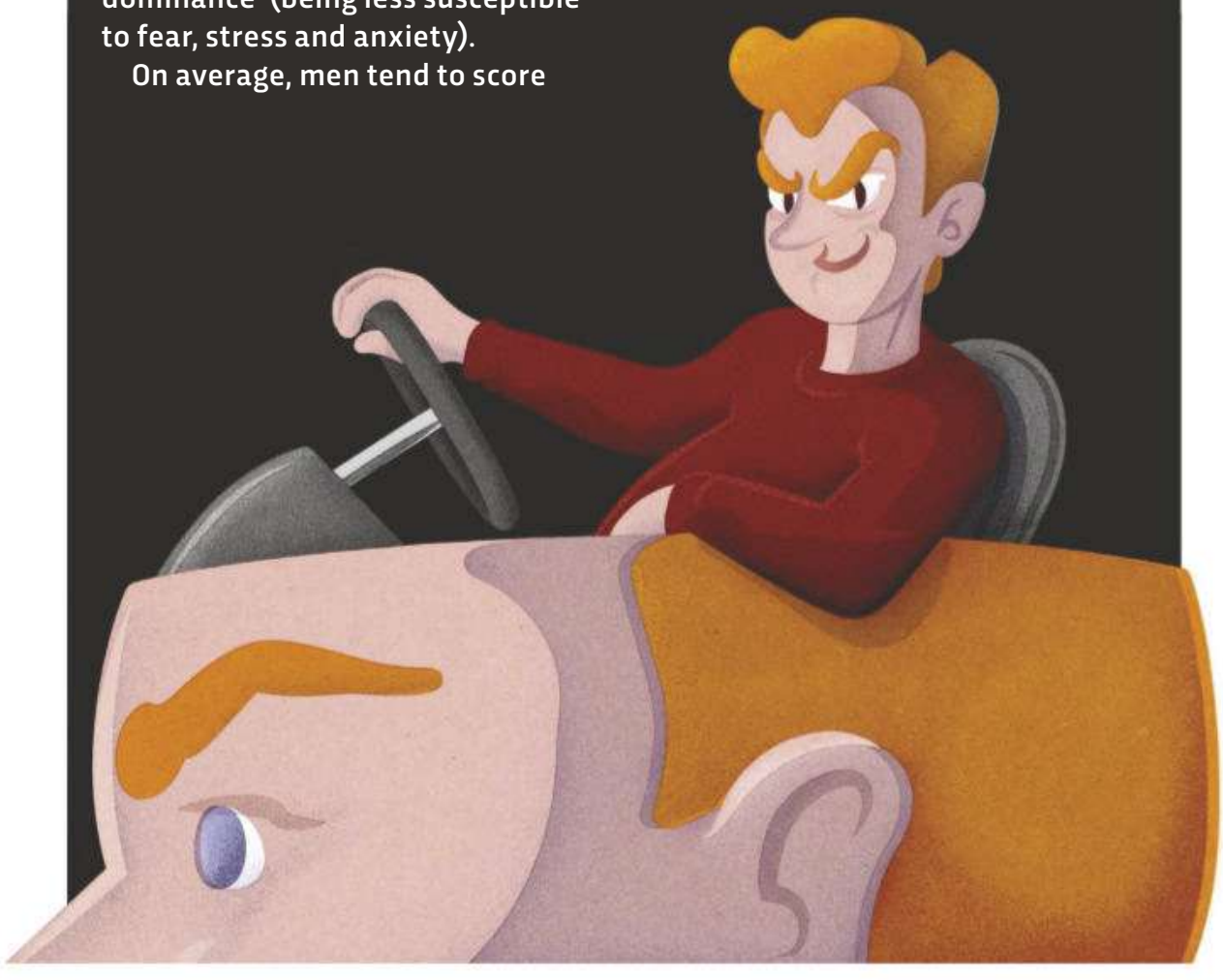
COULD I BE A PSYCHOPATH AND NOT KNOW IT?

If you were a psychopath in the Hollywood sense (think Hannibal Lecter), it would be odd if you didn't realise that, at the very least, you're 'different' and simply not very nice. After all, this kind of psychopath is essentially an aggressive sadist hiding behind a mask of superficial charm.

However, psychologists are increasingly realising that you can score highly on one or more psychopathic personality traits without having criminal or violent tendencies. These traits, which we all score on to some greater or lesser degree, include 'self-centred impulsivity' (how selfish you are), 'cold heartedness' (how much you're switched off from other people's suffering) and 'fearless dominance' (being less susceptible to fear, stress and anxiety).

On average, men tend to score higher on these traits than women. And don't tell your boss, but people in management positions also generally score higher, as do people holding far-right or racist views.

Yet 'fearless dominance' can be extremely useful in certain challenging or risky lines of work, such as surgery, special forces, elite sport or political leadership. If you're completely unfazed by the prospect of cutting into a person's flesh, parachuting behind enemy lines, performing in front of thousands, or making decisions that will affect millions, there's a good chance that you're a high scorer in this trait. Perhaps without realising it, you could be what psychologists call a 'successful psychopath'. ***CJ***

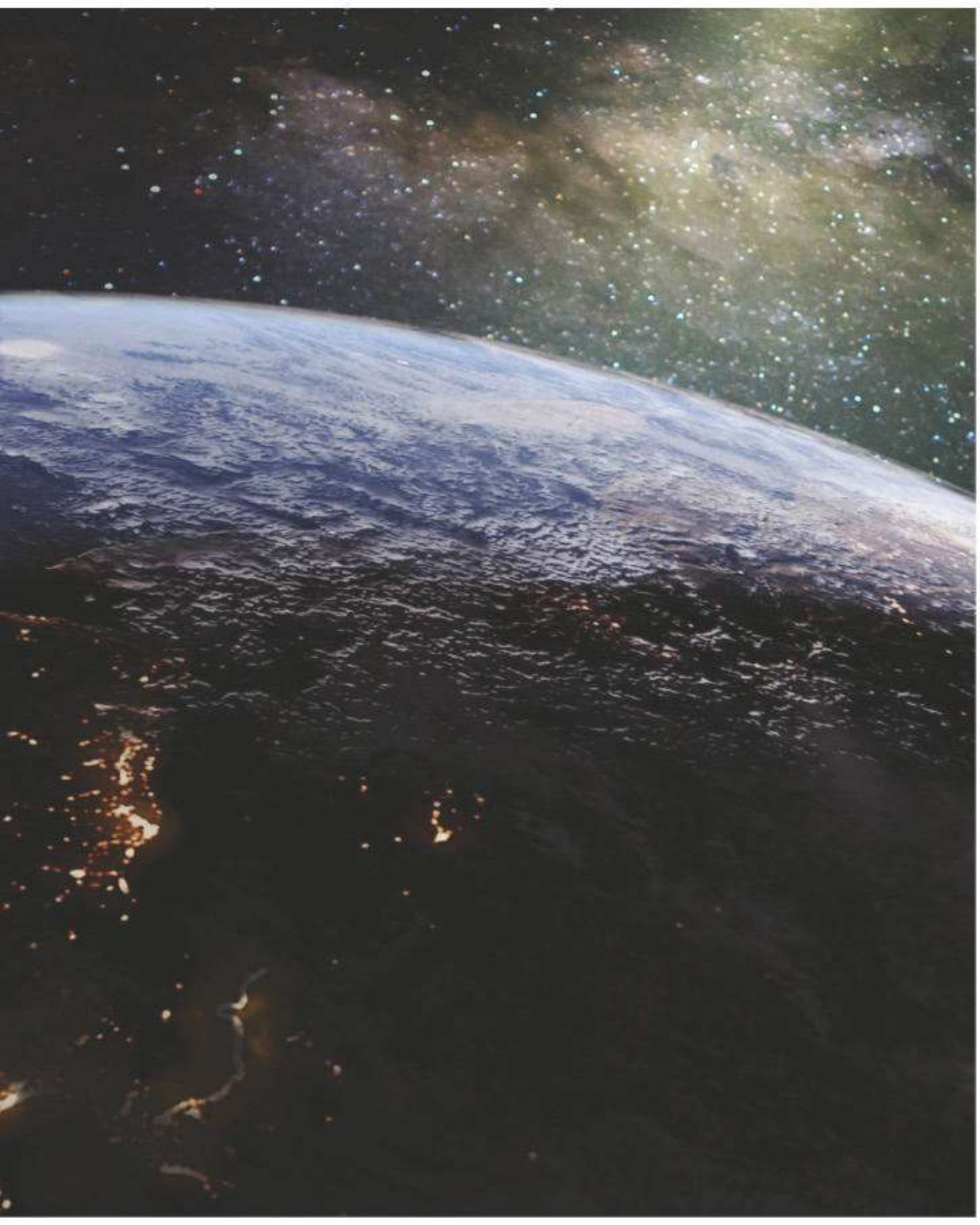


EMMA NEWBURY, BLACKBURN

SHOULD WE BE WORRIED THE SPEED OF EARTH'S ROTATION IS CHANGING?

We define a day as 86,400 seconds, or 24 hours – the time it takes for Earth to rotate once. However, the Earth doesn't rotate perfectly uniformly. Usually, the Earth's rotation is actually slowing down so that the length of the day increases by about 1.8 milliseconds per century, on average. This means that 600 million years ago a day lasted only 21 hours.

The variation in day length is due to several factors, including the tidal effects of the Moon



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and Sun, core-mantle coupling inside the Earth, and the overall distribution of mass on the planet. Seismic activity, glaciation, the weather, the oceans *and* the Earth's magnetic field may also affect the length of the day.

In 2020 scientists made a startling discovery. They found that, instead of slowing down, the Earth has started to spin faster. It is now spinning faster than at any time in the last 50 years. In fact, the shortest 28 days on record all occurred during 2020. As yet, scientists are not entirely sure what is causing this increase in Earth's rotation rate, but some have suggested it could be due to the melting of glaciers during the 20th Century, or the accumulation of large quantities of water in northern hemisphere reservoirs. However, experts predict that this speeding up is a temporary effect and the Earth will start slowing down again in the future.

But, for now, should we be worried? Although it will have no effect on our daily lives, there could be serious implications for technology such as GPS satellites, smartphones, computers and communication networks, all of which rely on extremely accurate timing systems. But such problems are ultimately surmountable, perhaps simply by subtracting a leap second rather than adding one.

So no, we shouldn't be worried – unless the shortening of the day is attributable to human activity. ***AG***

YOFAN TAMAYO, LONDON

HOW DO ANTS BREATHE?

Open your mouth and throat, but hold your diaphragm and chest absolutely still. You aren't quite holding your breath because some oxygen will still find its way into your lungs by the random diffusion of air molecules. However, it isn't nearly enough to keep up with the demands of your body. To survive without a diaphragm actively pumping air in and out of your lungs, you would need a much smaller body, or more than one throat. Ants have both. Depending on the species, ants have nine or 10 pairs of openings, called spiracles, along the side of their body.

Each spiracle is connected to an ever finer branching series of tubes called tracheae. This is similar to our lungs, except that insects don't use blood to carry oxygen from the tracheae to the rest of the body. Instead, the tracheae spread throughout the body and each branch ends in a cul-de-sac with a moist end-wall that touches directly against the membrane of a cell.

This system only works in tiny animals. Once the body grows beyond a centimetre or two, the tracheae are simply too long for air to be able to diffuse along them fast enough. Larger and more active insects have to supplement the passive breathing system by flexing their abdomens to pump air along the tracheae. But ant-size insects can manage just fine without this. In fact, a 2005 study at Berlin University found that many insects this size actually have to close their spiracles periodically so that they don't get too much oxygen! ***LV***

AMELIA CALDERBANK, RUNCORN

WHY DO SOME PEOPLE EXPERIENCE MORE VACCINE SIDE EFFECTS THAN OTHERS?

Vaccines work by showing the body a microbial mugshot of a tiny perpetrator (such as a virus or bacterium) that is a threat to your body. This triggers an immunological fire drill against the invader, enabling your body to react much faster and better to a real attack. It's this immune response that can cause some side effects.

Because everyone's immune system differs depending on multiple factors including genetics, age, biological sex, existing illnesses, and even our microbiome, it responds differently to vaccines. For example, an aged immune system has a good memory for dealing with pathogens it's seen before, but it isn't as good at dealing with novel diseases like COVID-19. Similarly, biological females have two X chromosomes compared to one for biological males. Many genes on the X chromosome are known to play a role in immunity, and marked differences between the sexes are being increasingly seen, with biological females having stronger immune responses. This translates to more side effects in women and fewer in the elderly.

QUESTION OF THE MONTH

SIMON BARTLETT, LEICESTER

DO ANIMALS PERCEIVE TIME DIFFERENTLY FROM US?

Time perception depends on how quickly the brain can process incoming information. Scientists have attempted to measure it by showing animals pulses of light, which start slowly and then speed up. There comes a point when the light is flashing so quickly, that it looks as though it is on permanently. Carefully placed brain electrodes can reveal when this moment occurs.

Studies show that smaller animals with faster metabolisms can detect higher frequencies of flickering lights than chunkier, slower animals. Just like Neo dodging bullets in *The Matrix*, movements and events may seem to unfold more slowly. Salamanders and lizards, it seems, perceive time more slowly than cats and dogs. And while this may help to explain the infuriating ability of flies to elude rolled-up newspapers, it also raises an important question: why?

From an evolutionary perspective, it makes sense for animals that need to respond quickly – for example, to evade predators or catch fast-moving prey – to perceive time at finer resolutions, but what's remarkable is that some animals appear to dial up or down their experience of time to suit their needs. Before they set off hunting, some swordfish, for example, boost blood flow to the brain, slowing their perception of time, and boosting the number of frames that they can process per second. It helps them to react more quickly.

Elsewhere, studies on mice have shown that time perception can be speeded up by stimulating dopamine-producing neurons in the brain. These findings have profound implications for people with dopamine-related disorders, such as attention deficit hyperactivity disorder (ADHD). Here, there is a reduction in dopamine, so sufferers could perhaps be impulsive because they perceive time more slowly. Conversely, drugs that boost dopamine levels may be of use, because they speed up the perception of time. However, this is only a working hypothesis, so for now, only time will tell. ***HP***

WINNER

Simon wins a **bundle of science books from Bloomsbury**, worth more than £63. *Ouch!* investigates our relationship with pain; *Models Of The Mind* explores how maths, physics and engineering have shaped our understanding of the brain; *The Brilliant Abyss* takes us on a thrilling expedition into the deep sea; and *Overloaded* reveals how every aspect of our lives is shaped by brain chemicals. **bloomsbury.com**

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Side effects may be linked to the use of adjuvants. When safely added to some vaccines, these materials (such as aluminium), can further fire up the immune system when a bigger response is needed than the microbial mugshot alone can provide.

If you feel headachy, fatigued and even feverish post-vaccine, it's a sign your immune system is working. These physical signs of the body's response to vaccination even have a name: reactogenicity. But don't blame the vaccine's microbial elements entirely. Other factors include administration – the angle, needle size, location and speed of vaccination can all play a role.

If your arm hurts, remember that not only is your immune system reacting and releasing chemicals to stimulate an immune response, but you've also just been stabbed in the arm with a needle! ***SO***

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MICHAEL CHANDLER, HEREFORD

DO WE GET OUR GUT BACTERIA BEFORE OR AFTER BIRTH?

We each have trillions of bacteria living in our gut and this microbiome plays important roles in digestion and fighting disease. Their origins have long been debated, but two large-scale studies in 2019 offered some answers. In one, researchers retrieved more than 500 placentas from women shortly after giving birth, and found the healthy placentas were sterile. Another study reported that babies delivered by caesarean lack certain strains of beneficial bacteria. Taken together, the research indicates we pick up our microbiome during and shortly after birth. ***CA***

ASTRONOMY FOR BEGINNERS

Perigee full Moon
'Supermoon' appears 14 per cent bigger and 30 per cent brighter than a 'Micromoon' as seen from Earth
Apogee full Moon
'Micromoon'

ALL YOU NEED TO KNOW ABOUT MAY'S SUPERMOON

WHEN: 26 MAY

This month, stargazers around the world will see the second supermoon in two months (following the one on 26 April). On average, one in every 14 full Moons will be a supermoon, but they sometimes come two in a row because of the cycle of the Moon's orbit and its phases briefly syncing together.

But what causes a supermoon in the first place? The Moon doesn't orbit Earth in a circle, thanks to being pulled around by various gravitational forces like the Earth and the Sun. Instead, it moves in an elliptical shape, and how close it gets to Earth varies month by month.

At a certain point in its orbit, called perigee, the Moon is at its closest to Earth. Then at another point, apogee, it is furthest away. The difference between these two points is an average of 48,000km.

A supermoon occurs when we have a full Moon at the same time the Moon is at perigee. This makes it appear up to 14 per cent bigger and 30 per cent brighter than a full Moon at apogee (when it's furthest away and looks smaller and dimmer).

The name 'supermoon' was first suggested by astrologer Richard Nolle in 1979, but it has since been adopted by the mainstream.

Each month, the full Moon has a different name, mostly in reference to whatever is usually happening at that time of year. In May, it's the Flower Moon, named after – you guessed it – all the plants that bloom at the end of May as summer starts to emerge in the northern hemisphere. ***AB***

TOP TEN

WORLD'S LONGEST BRIDGES

Many have floated the idea of a bridge between England and mainland Europe. This Channel-spanning bridge would need to be 35km long, a distance that would make it the lengthiest bridge in Europe – well beyond Portugal's 17km Vasco da Gama Bridge. However, such a construction still wouldn't break into the world's top 10 longest.

1 THE DANYANG-KUNSHAN GRAND BRIDGE
CHINA
164KM

2 CHANGHUA–KAOHSIUNG VIADUCT
TAIWAN
157KM

3 CANGDE GRAND BRIDGE
CHINA
116KM

4 TIANJIN GRAND BRIDGE
CHINA
113KM

5 WEINAN WEIHE GRAND BRIDGE
CHINA
79KM

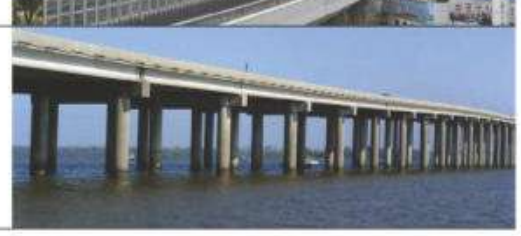
6 BANG NA EXPRESSWAY
THAILAND
54KM

7 BEIJING GRAND BRIDGE
CHINA
48KM

8 LAKE PONTCHARTRAIN CAUSEWAY
USA
38KM

9 WUHAN METRO BRIDGE
CHINA
37KM

10 MANCHAC SWAMP BRIDGE
USA
36KM



SARA FLYNN, PORTSMOUTH

HOW CAN I GET BETTER AT ARGUMENTS?

Science can definitely help here, thanks to 'erisology': the study of disagreements. For instance, ever had your mind go blank when asked to explain your side of an argument? A study in journal *Psychological Science* indicated that people who claim to know what they're talking about often aren't able to articulate their argument well, so begin by asking your opponent in detail what exactly they believe. The same study found that the act of explaining also dilutes extreme views, so this could really help your case.

Didn't work? Exercise moral foundations theory. Proposed by social psychologist Jonathan Haidt, it suggests our moral 'taste buds' exist in six major areas: care, fairness, loyalty, authority, sanctity and liberty. A 2017 study outlined that left-leaning folk prioritise care, while right-wingers favour loyalty, authority and sanctity. Liberty and fairness are important across the board, so try reframing your argument according to your opponent's beliefs.

What about eye contact? If you're talking, avoid it. That's the argument put forward by one University of British Columbia study that observed participants with opposing views state their cases on controversial issues. Using eye-tracking technology, the researchers found the more time participants spent looking at a speaker's eyes, the less persuaded they were by their argument. In short: follow this rule, and only victory should be in your sights. ***LS***

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CAN SPACE EXPLORATION BE ENVIRONMENTALLY FRIENDLY?

Lift-off is usually the most environmentally harmful stage of any space mission, with vast quantities of fuel burnt up in a matter of minutes. For instance, SpaceX's Falcon 9 gets through 112 tonnes of refined kerosene, emitting about 336 tonnes of CO_2 (the equivalent produced by your average car driving almost 70 times around the world). As well as greenhouse gases, rocket engines emit chlorine and particles of soot and aluminium oxide that destroy ozone. These issues are growing more pressing with the advent of commercial spaceflight. There were 114 space launches in 2020, but there may be up to 1,000 per year in future.

Sustainable fuels are the top priority to enable greener space travel. Current spacecraft use a variety of fuels, but most are based on fossil fuels. One potentially greener option is liquid hydrogen and oxygen, used by the New Shepard Propulsion Module from private spaceflight company Blue Origin. Hydrogen can be obtained sustainably by using solar power to break water down into oxygen and hydrogen molecules.

In 2019, NASA's Green Propellant Infusion Mission (GPIM) road-tested AF-M315E, a green alternative to hydrazine (a toxic component of many types of rocket fuel) and hopes to use this to power future missions.

Reusable rockets can cut down on some of the waste associated with spaceflight. Traditionally, boosters, fuel tanks and other components are treated as expendable. But guiding them back to Earth in a controlled manner opens new possibilities – most components from the Falcon 9 can be reused up to 100 times.

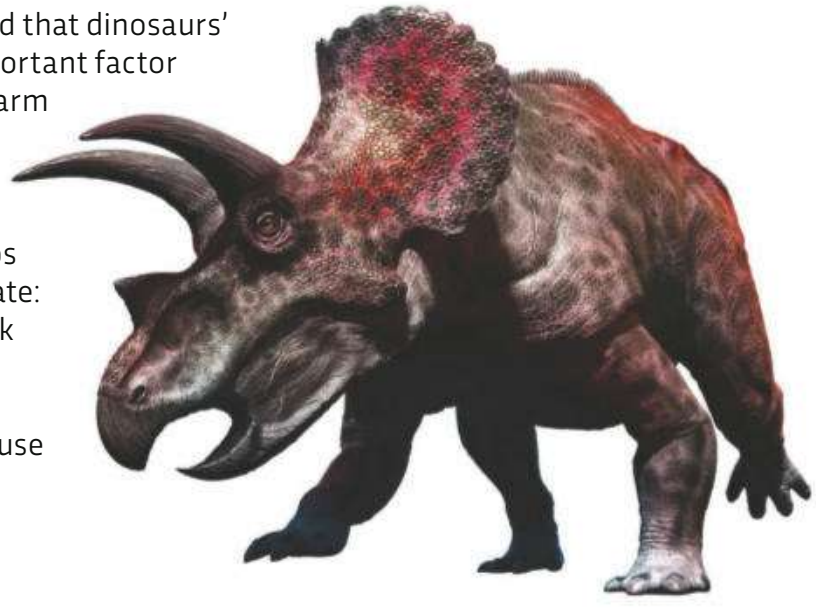
Truly environmentally friendly space travel is still some way off. But we already have many of the technologies needed to start limiting its impact on our planet. ***AFC***

CHIEDZA MCNAB, LIVERPOOL

DID DINOSAURS FART?

Yes! Just like dogs, some insects, and even millipedes, dinosaurs undoubtedly would have passed gas.

Not only did *Brontosaurus* and *Triceratops* make wind, but they would have made a lot of it. So much, in fact, that it affected the entire Earth and its climate. One study found that dinosaurs' 'emissions' were an important factor in keeping the planet warm and moist during the Mesozoic Era (250 to 65 million years ago). Similarly, farts and burps shape our modern climate: emissions from livestock account for more than 10 per cent of all anthropogenic greenhouse gas emissions today. ***SB***



EMILY WILSON, BIRMINGHAM

WHY ARE BUBBLES ROUND?

Bubbles occur when a thin film (for example, of soapy water) traps some gas (for example, air). The molecules in the film are attracted to each other, which not only holds the film together, but also makes it shrink to the smallest possible area.

The smallest area enclosing any given volume? A sphere. Therefore, the film will shrink to cover a sphere, and then can't shrink any further because of the trapped air. Thus, bubbles end up as round. ***JB***

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THE EXPLAINER

WHAT HAPPENED TO THE DENISOVANS?

WHO WERE THE DENISOVANS?

In short: not even scientists are sure. In a bit longer: the Denisovans are an extinct relation to modern humans who lived in Siberia and East Asia. Some experts have argued that Denisovans are an entirely new species of our genus, *Homo*, but others think that they are merely eastern Neanderthals.

Unfortunately, it is hard to know the exact time period that they walked our planet as very few Denisovan fossils have been discovered. However, the fossils we do have indicate they inhabited southern Siberia's Denisova Cave (hence 'Denisovans') 50,000 to 200,000 years ago. Plus, a Denisovan partial mandible discovered in a cave in the Tibetan Plateau indicates that they could be found in the region over 160,000 years ago at least.

These findings suggest Denisovans were the contemporaries of Neanderthals and even *Homo sapiens* (who first emerged about 300,000 years ago). In fact, DNA evidence suggests Neanderthals and Denisovans both lived in Denisova Cave, although probably not at the same time.

HOW WERE THE DENISOVANS DISCOVERED?

Denisovans were the first group of humans to be discovered based on their DNA alone. However, this was largely by accident. In 2010, German geneticist Prof Johannes Krause (then a PhD student) was extracting mitochondrial DNA from what he thought was a Neanderthal finger bone found in Denisova cave. It wasn't Neanderthal. Krause had instead stumbled upon a new lineage, the Denisovans.

This find left researchers in the strange and unprecedented position of having the entire Denisovan genome sequenced while not having a single significant Denisovan fossil besides some small bone fragments, a few teeth and one pinky bone.

Then, in 2019, the right half of a mandible found during the 1980s in the Tibetan Plateau's Baishiya Karst Cave was analysed. While no ancient DNA could be extracted from it, protein analyses indicated that it was Denisovan.

WHAT DID DENISOVANS LOOK LIKE?

Even with hundreds of fossils, we still have many questions about what the Neanderthals looked like – imagine what it is like with a species only discovered in 2010 without even a partial skull to their name!

But although ascertaining what the Denisovans looked like is incredibly difficult, there are some clues. The few fossils we have suggest that the Denisovans had big teeth, a large stocky jaw and possibly a flattened and broad neurocranium (braincase).

Amazingly, their appearance can be partly recreated through a new technique using DNA methylation. Rather than examining the DNA itself, this promising (but contested) method does not look at the DNA itself *per se*, but the activity of the DNA and how it is expressed. Using this, scientists predict Denisovans wielded a wide pelvis, large ribcage and joint surfaces, low forehead and broader skull.

MAAYAN HAREL X2, DONGJU ZHANG/LANZHOU, GETTY IMAGES, SCIENCE PHOTO LIBRARY

DID THEY EVER MATE WITH NEANDERTHALS?

Yes! In fact, one small 2.5cm bone fragment found at Denisova cave in 2012 caused quite a stir. At first it went unrecognised, stashed alongside thousands of animal bone fragments for four years. However, after being identified as a hominin bone by researchers at Oxford University, it was sent off to the Max Planck Institute for further analysis.

The final result: in 2018 it was announced that this 90,000-year-old bone belonged to Denny (as she was affectionately known), a girl who had a Neanderthal mother and a Denisovan father.

How unlikely is it that with a little over a dozen Denisovan fossil fragments in existence, one would belong to such a 'hybrid'? Was this a fluke or did such mating happen all the time?

WHY DID THE DENISOVANS DIE OUT?

We're not exactly sure how the Denisovans died out, with no evidence of an environmental catastrophe. It's certainly possible that *Homo sapiens* outcompeted the Denisovans, but, again, there is no proof here.

We aren't even sure *when* the Denisovans died out, with limited DNA evidence even suggesting they may have survived in New Guinea or its surrounding islands until 15,000-30,000 years ago.

However, we do know that *Homo sapiens* mated with Denisovans numerous times – and that this crossbreeding benefited today's humans. For instance, the EPAS1 gene variant that modern Tibetans and Sherpas inherited from Denisovans makes them better adapted for living at high altitudes, protecting them from hypoxia (a condition where tissues in the body are deprived of oxygen).

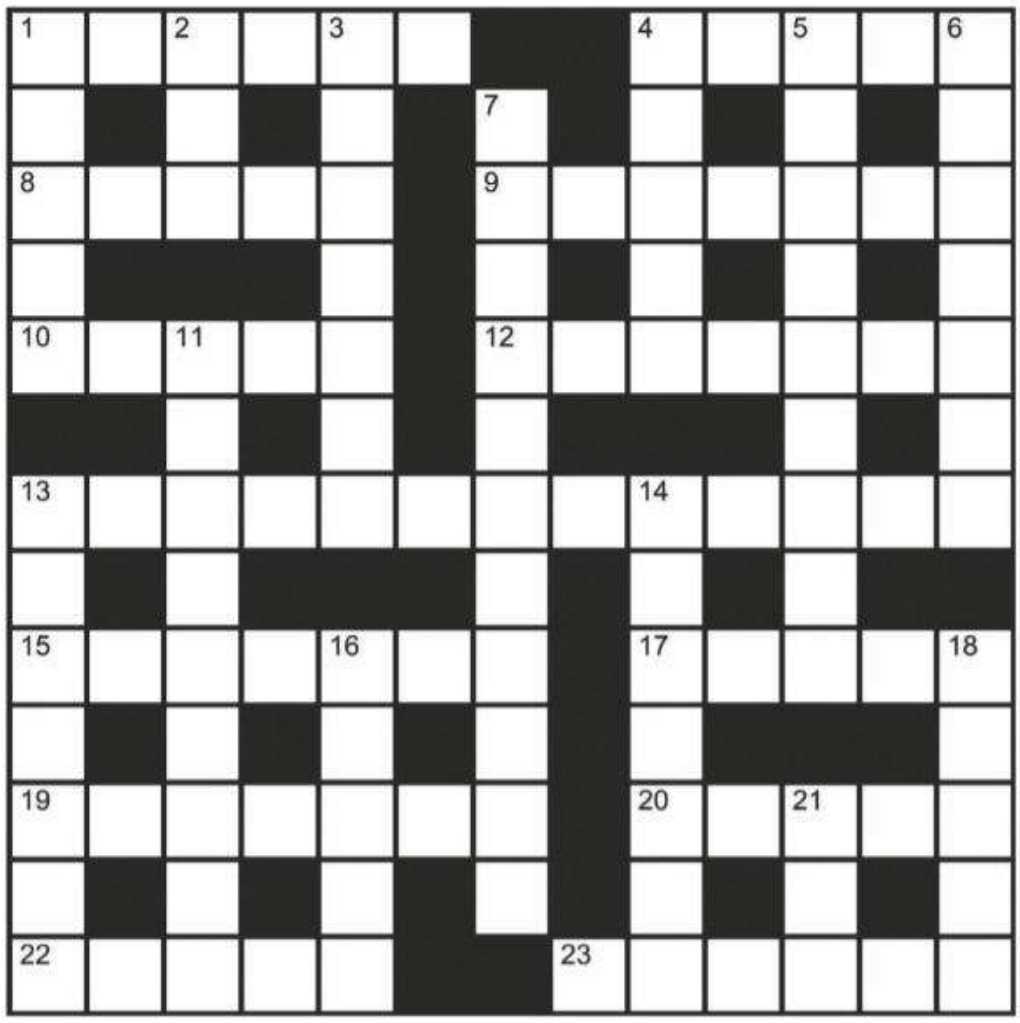
Similarly, scientists have even discovered that some modern populations in Oceania have an immune system that's partly coded (and bolstered) by DNA acquired from Denisovans.

by ELLA AL-SHAMAHI

Ella is an explorer, TV presenter and author of The Handshake: A Gripping History *(£10.99, Profile Books).*

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

1 Flight points towards headland (6)
4 Surrey's top dean broke chair (5)
8 Gone off a city (5)
9 Develop flower, having shapeless edges (7)
10 List an item of furniture (5)
12 Edward promises to be dull (7)
13 Caribbean films showing summer attire (7,6)
15 Flier right to tug back on evidence of drinking (4,3)
17 Crook to include large mixture (5)
19 Scared, drunk, having one cocktail (7)
20 Giant bird article (5)
22 Developing roots or trunk (5)
23 Snide creep concealing order (6)

DOWN

1 Rowers had dinner, we hear (5)
2 Tin is minimal without borders (3)
3 Gold crockery starts to level off (7)
4 His last name for a weapon (5)
5 Daughter is on track for conversation (9)
6 Arch-enemy seems in a bad way (7)
7 Sailor carts off flan – that's not realistic (8,3)
11 Exclude sensitive publican (9)
13 Tabby is upset, mind (7)
14 Frequent visitor in Brussels, returning, following custom (7)
16 Lizard returning average note, say (5)
18 Scandinavian has catholic routine (5)
21 Pitch – begin removing ends (3)

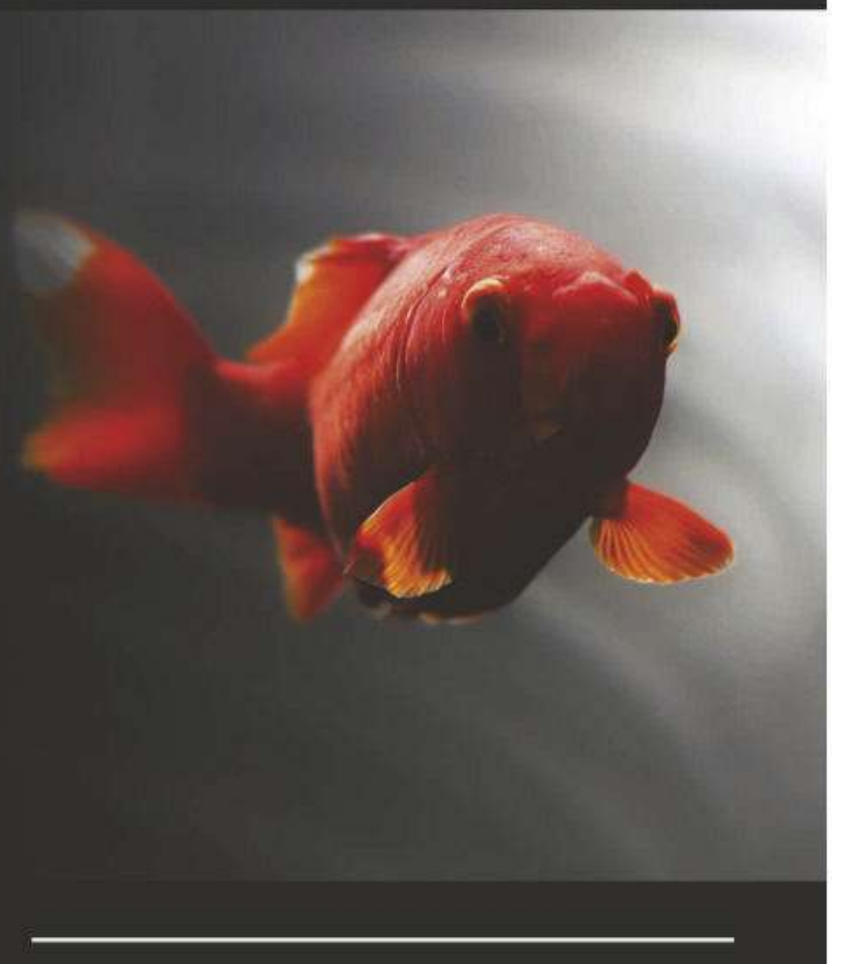
ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

SPACE CRITTERS

Animals may be poised to act as companions or lunar livestock.



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The people who are using technology to upgrade their bodies.

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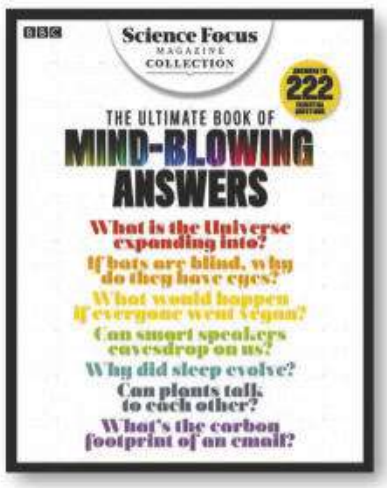
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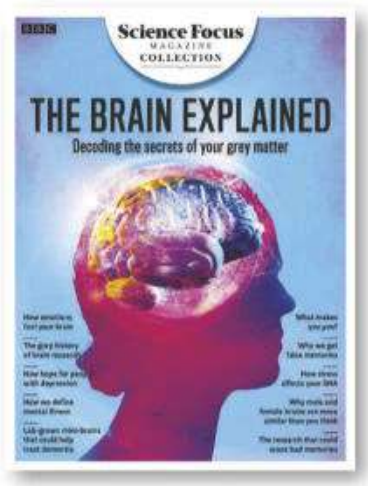

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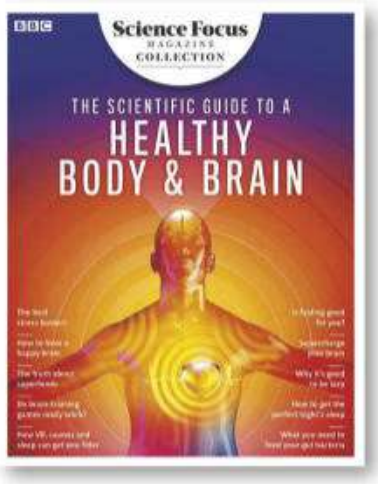

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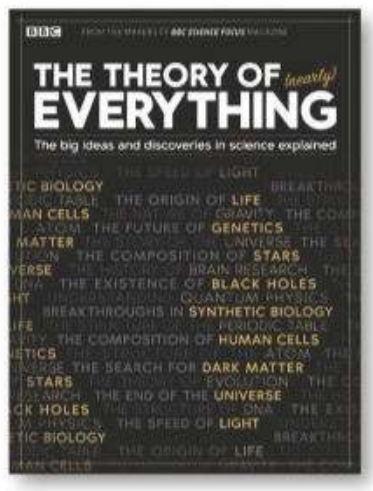

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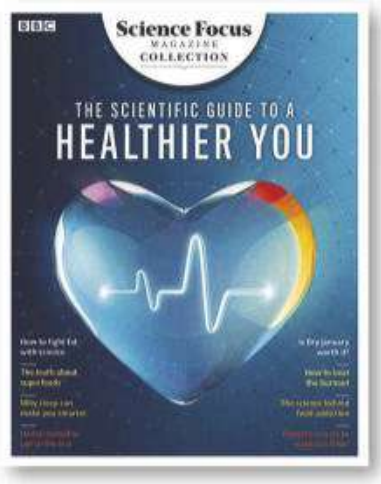

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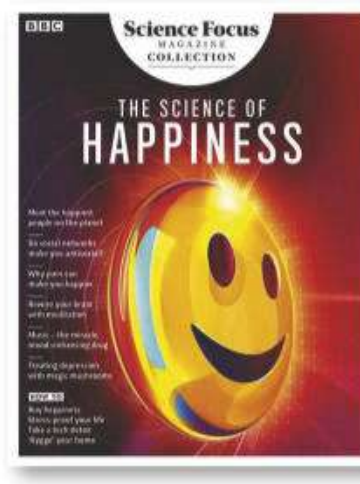

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A SCIENTIST'S GUIDE TO LIFE

HOW TO BAG THE BEST HOLIDAY

THINKING OF BOOKING A SUMMER HOLIDAY? WHEREVER YOU'RE PLANNING ON GOING, ANALYTICS CONSULTANT **ANDREW WILLSHIRE** IS HERE TO HELP YOU BEAT THE ALGORITHMS AND BAG THE BEST DEAL...

HOLIDAY PRICES ARE SET BY ALGORITHMS

An algorithm is just a set of instructions. Companies want to maximise their profits, but they know, for example, that if they sell all their holidays too cheaply and quickly, they won't make as much as they could have. Algorithms are used to constantly update prices according to what has already been sold, and to predict how likely people are to buy a holiday at a certain price. They're based on the data that our online activities generate.

CLEAR YOUR COOKIES

If someone looks at the same holiday three times but hasn't bought it yet, the algorithm 'knows' the person is very interested. It might therefore increase the price in order to rush the person into a sale, and make the most money from that person that it can. This is why it sometimes pays to clear cookies or browse in Private Mode, as it deprives the algorithm of the information that you've looked at the holiday before.

BOOK IN A LOCAL CAFÉ

The algorithm 'knows' roughly where you are from the IP address of your computer network, so it can tell if you are in a more or less affluent area. It also 'knows' that the price a person can afford to pay affects whether they will book, so it might offer a lower price to someone in a poorer neighbourhood. You can exploit this by booking your holiday from the coffee-stocked comfort of a carefully chosen café.

BE PREPARED TO GO LAST MINUTE

An empty room is worth nothing to a holiday company. As you get closer to the departure date, prices will fall. To get the best prices, pick a holiday that starts tomorrow! You might not get the exact location you want, but you will get a good deal.

DON'T BE TOO CHOOSY OVER WHERE YOU GO

Some websites only tell where you're going after you've booked. As long as you're not fussy about where you go, you can get some great deals. Hotels that buy into these schemes realise that sometimes it pays to sell a guaranteed number of cheaper rooms, rather than a smaller, less predictable number of pricier rooms.

LOOK ACROSS MULTIPLE WEBSITES

Sometimes different companies use different algorithms to price the same holiday. This means they may offer you different prices, but check you are being offered like for like. Do they both include breakfast, for example, or are airport transfers extra?

WORK OUT WHAT THINGS ARE WORTH TO YOU...

... be it the presence of a swimming pool, the airline you fly with, customer service, or the amount of time spent you're prepared to spend trawling different websites for the best deal. If you're honest about what things are worth to you, then an algorithm will never get the best of you because you already know what you're happy to pay. And be prepared to walk away. There are few things that you won't get a second chance to buy.

TALK TO PEOPLE

You can't haggle with an algorithm. They're not driven by emotion. They're driven by data. We book online because it's the easy option, but never forget the value of talking to an actual human. Phone or visit your travel company. You might find that their salespeople are prepared to unlock deals that you would never get online. SF

ANDREW WILLSHIRE
Andrew is an independent analytics consultant and founder of the strategic analytics consultancy Diametrical.
Interviewed by Dr Helen Pilcher.

NEED TO KNOW...

1

Surf booking sites from the comfort of a non-local café, and you might just find a better deal for your holiday.

2

Book the holiday at short notice and you're more likely to get a great deal (as long as you aren't fussy about where you go).

3

Contact your local travel company, as they're often able to unlock better deals than what you'll find online.

ILLUSTRATION: AVALON NUOVO

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